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UNCONTROLLED STORAGE TEST OF THE MODULAR ARTILLERY CHARGE SYSTEM (MACS)

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January 2004

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14. ABSTRACT

Uncontrolled storage test of the Modular Artillery Charges System (MACS) M232 charge was conducted at Yuma Proving Grounds in 2002. The test was conducted to determine effect of ambient temperature conditioning on muzzle velocity precision. Data from this test shows that a group of charges stored in the packaging containers in the Yuma desert environment during summer months did not exhibit degradation in muzzle velocity standard deviation when compared to charges conditioned to a uniform temperature in a conditioning box.

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BACKGROUND

For years, the Artillery community has studied and identified powder temperature as an important parameter in determining the fire control solution for a mission.

Tabular firing tables as well as digital fire controls are designed to correct the expected projectile trajectory for the difference in powder temperature from the normal, defined as ambient or 21°C. The powder temperature is recorded periodically (usually morning and afternoon) by inserting a M1 powder thermometer into one charge assumed representative of the combat load. The recorded temperature would, in essence, adjust the group's center-of-impact based on the assumption that all charges were approximately the same temperature.

Until recently, this was an acceptable procedure, especially when one considers the technology that was previously available before digital fire control evolved. Without a computerized fire control system for each weapon, the burden to correct every round for powder temperature would be unmanageable. However, with the leap-ahead weapon systems, such as, Crusader and, subsequently, NLOS-C, the necessary technology needed to correct every firing for individual temperature could be integrated into every platform, albeit, at a cost. With these advanced weapons delivering high volumes of fire support at high rates and multiple targeting, there is significant savings in the logistic area if better precision can be achieved, thus potentially offsetting the cost of the temperature management system.

Studies by other agencies, based on historical temperature sensitivity with bag charges, showed one of the drivers to achieving improved precision is management of the propellant temperature. Contrary to that analysis was a study done by the Modular Artillery Charge System (MACS) team on conditioning temperature. The concern of the study was to determine the minimum conditioning time required to bring the MACS to equilibrium during temperature conditioning. The MACS is the next generation propelling charge, contained in a combustible case to achieve rigidity for auto handling in the new artillery weapon systems. The combustible case is an excellent thermal insulator. A study performed at Yuma Proving Grounds with thermocoupled XM230 charges (the predecessor to the M232 charge) in September 1997 showed that a minimum conditioning time of at least 16 to 20 hrs was required to achieve a constant temperature throughout the charge (fig. 1). During this test, on Day 1 charges were conditioned from their 70°F ambient temperature to –60°F, on Day 2 the charges were brought back to 70°F from –60°F. On Day 3, the charges were conditioned from 70°F to 145°F and finally on Day 4, the charges were conditioned from 145°F to –60°F.

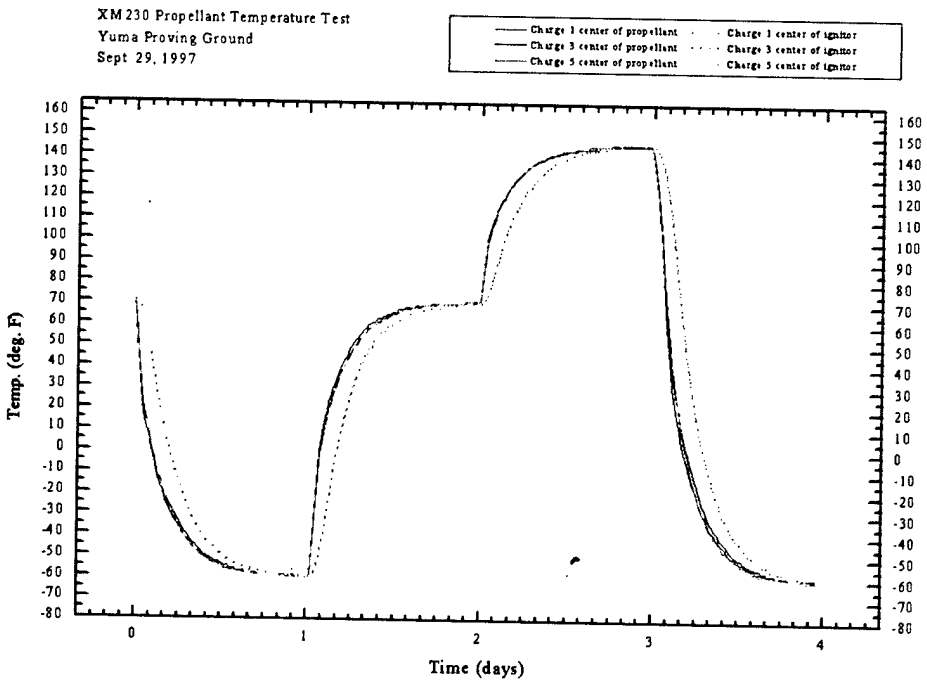


Figure 1
XM230 propellant temperature test at Yuma Proving Grounds (September 1997)

Responding to the studies indicating a need for thermal management of the propellant, a Radio Frequency Transponder (RF Tag) program was conducted. The RF Tag had the capability of measuring temperature within the MACS; however, the placement of the tag location was in question. An extensive firing test (partial-soak test) was conducted with thermocoupled charges conditioned along side the test charges in August 1998. Since the thermocoupled charges were not to be fired, there was a thermocouple placed in nearly every conceivable location, given the symmetry of the charge. The best correlation achieved between velocity and measured temperature was at the center of the ignition powder, located at the geometrical center of the charge. Reference Partial-Soak Test data conducted in August 1998.

The MACS team, however, was skeptical to the value added of any temperature management system for individual charge temperatures, given the results of the temperature conditioning study and the RF Tag program. Given the long time to achieve thermal saturation and the critical charge location being the last area to react to a temperature change, an additional study was justifiable to further evaluate the value of managing individual temperature. The study is the basis of this report.

INTRODUCTION

As stated in the Background, the objective of the test program of this report was to evaluate the degradation of muzzle velocity consistency brought on by the non-uniform temperature distribution. The most severe condition conceivable was a freestanding pallet of M232 propelling charges subjected to desert conditions with it's corresponding temperature swings from day to night and the severe solar loading. During this test, the palletized M232 charges

were exposed to temperatures up to 45°C and temperature ranges of up to 20°C. The M231 propelling charge was not subjected to similar testing because its sensitivity to temperature is considerably less than that of the M232 propelling charge.

No conditioning by the howitzer's magazine structure occurred during these tests due to the limited exposure of the propelling charge to the magazine temperature, 10 min maximum. Therefore, no evaluation or conclusions can be made regarding increment temperature distributions as a result of extended storage in a self-propelled howitzer (SPH) propellant storage magazine.

The test was actually conducted in two phases. The first phase, phase 1, compared the ballistic performance of charges conditioned by the local ambient environment at Yuma Proving Ground to charges of the same lot conditioned in a controlled conditioning box held at 21°C. The data generated from this test was evaluated by comparing each test group to the control group that was fired adjacent to the test group. Based on the results of phase I, showing the need for a temperature management system for individual charge temperature was unnecessary for this situation where the charges are loaded directly from pallets into the weapon and fired. Further testing was desirable to increase the confidence level for any subsequent decision. The control rounds were eliminated during subsequent testing (phase 2) to save costs and, therefore, only test groups were evaluated. A test group consisted of palletized charges exposed to desert conditions (without the use of a tarp as described in current field manuals to establish an extreme condition).

DISCUSSION

Phase 1

The first thought of the test program was to simply compare charges subjected to uncontrolled temperature conditioning with charges temperature conditioned. The worst case conceived was to subject a pallet of charges to desert conditions, expecting the largest solar loading possible. It was decided to perform the test at Yuma Proving Grounds leaving the test sample in the desert unprotected from solar loading and to condition a sample from the same lot to a constant 21°C for a minimum of 24 hrs. The test charge increment temperature was derived from the recorded temperature of the increment thermal emulators (ITEs). The ITEs are inert simulators of the MACS charges that maintain the true thermal conductivity of the live charges, but are inert and instrumented to record the temperature as a function of time. They are a product of a MACS contract with West Point. Next to the test sample pallet, a shadow pallet was placed containing the ITEs. The test assumed equality of temperature for increments in identical location within the pallet of both the "shadow" and "test" groups. The ITEs were distributed throughout the shadow pallet with live charges making up the difference.

For each charge, the individual increment temperatures were averaged to obtain a "charge" temperature based on a prior study by the Army Research Laboratory that showed under conditions where the temperature variation was less than 20°F, averaging the temperatures of the individual increments correlated very well with their performance level. Thus, that approach was adapted for this study.

Table 1 is a summary of the standard deviation and range of the temperatures for test groups, and the standard deviation in muzzle velocity for both test and control groups (control groups are assumed to have no variation in temperature based on temperature conditioning at constant temperature for over 24 hrs). The first number of the ID column represents the zone the charge was fired and second number indicates the occasion of firing; e.g., 3-1 is the first occasion at zone 3. For occasion 6-3, only one temperature data point was collected, therefore, range and standard deviation information is unavailable.

Table 1
Summary of temperature and muzzle velocity variation

ID	T sd©	T range©	T MV SD	C MV SD
3-1	1.0	2.4	1.7	1.2
3-2	0.5	1.0	1.2	2.6
3-3	0.7	1.3	1.2	2.0
4-1	2.7	5.9	1.1	1.1
4-2	0.2	0.6	1.1	1.5
4-3	2.7	6.1	2.5	1.0
5-1	0.7	1.3	1.8	1.5
5-2	0.9	1.7	1.8	2.5
5-3	1.2	3.4	1.4	0.8
5-4	1.4	3.0	1.3	2.4
55	1.9	4.6	1.8	0.4
6-1	2.5	5.6	1.9	1.6
6-2	2.3	5.0	1.6	1.1
6-3			0.9	2.3
6-4	0.7	2.1	1.3	1.0
6-5	2.7	5.8	1.7	1.3

Figure 2 shows the temperature delta between the highest and lowest measured charge for each group.

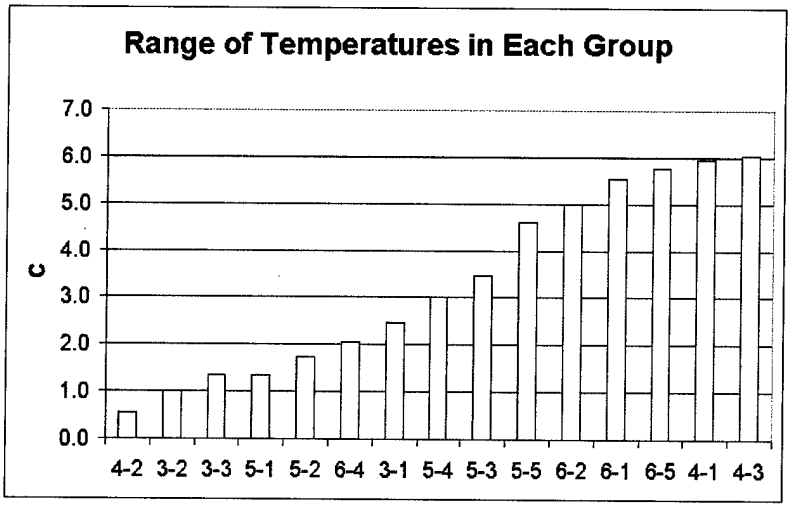


Figure 2
Range of temperatures in each group

A comparison of the muzzle velocity standard deviation for the test and control groups for zones 3 to 6 is presented in figure 3. The velocity standard deviation of the test groups did not exhibit degradation when compared to the control groups, even though there was a measurable difference in temperature between propelling charges. Under the scenario tested, all test groups exhibited a distribution of charge increment temperatures less than 3°C, a level once considered a requirement for Crusader. It is assumed the same would hold for NLOS-C, unless there are significant requirement changes in the future for transfer and firing rates.

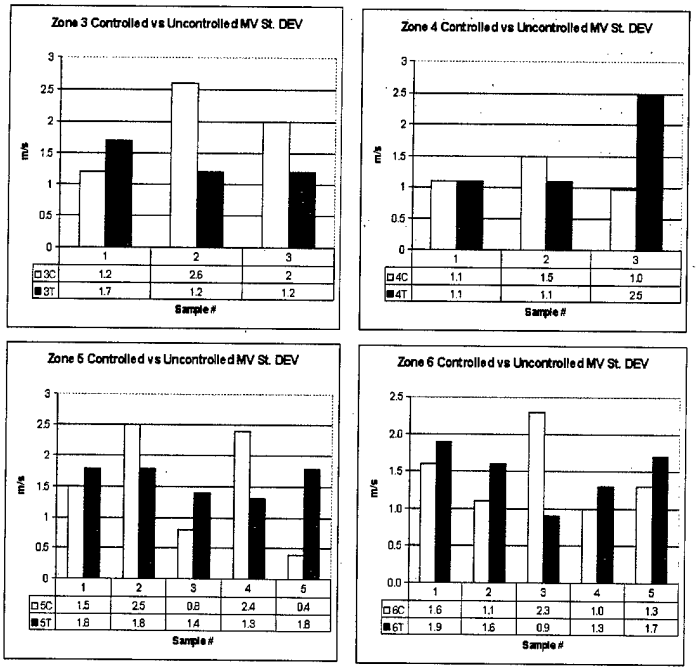


Figure 3
Muzzle velocity standard deviation comparison for zones 3 to 6

As can be seen from the results of the testing, the test group variability was no worse than the control groups, in fact, on several occasions (6 out of 16), the uncontrolled temperature samples did better than the samples subjected to controlled storage conditions. It was decided that a second phase (pPhase 2) be performed to confirm the results and conclusions drawn on the first test. To reduce costs, the conditioning boxes being a cost driver, the control groups were eliminated. This allowed for substantially more testing of uncontrolled temperature samples. Additionally, the testing in phase 2 was further limited to zone 6 to maximize the database at the highest velocity level where the maximum effect of temperature variability is expected.

Phase 2

Phase 2 of the testing to evaluate temperature variability effects on muzzle velocity uniformity (precision) was conducted during 14 August to 25 September 2002 from SPH1 at Yuma Proving Ground. The charges were again conditioned in the Yuma desert environment in the packaging containers on a pallet. Charges were chosen for each group across the pallet to obtain a cross section of temperature ranges as expected to be the worst case in real life if the charges are uploaded in to a SPH. The internal temperature was obtained for a sample of these charges to determine the average temperature for each group. For this phase, a group consisted of 15 zone 6 rounds or 90 M232 propelling charges uploaded at one time into the SPH1. Every effort was made to test each group as one set, but faults generated in the SPH1 sometimes caused a break in cadence of sufficient duration to split the group into two. Such occasions are noted in the table by sample sizes smaller than 15 for the group. Table 2 is a summary of the group's average temperature, temperature range between coolest and hottest charge measured, and the ambient air temperature when the data was obtained. The Day-Zone-Occ column represents which day of the test, zone, and the occasion number for that day; e.g., 1-6-1 is the first day, zone 6, occasion 1.

Table 2
Phase 2 results

Day-zone-occ	N	Ambient	Chg T avg©	Chg T range©	MV std dev
1-6-1	15	38	32	2.8	1.4
1-6-2	15	42	34	1.8	0.9
1-6-3	15	44	40	3.1	2.9
1-6-4	15	44	42	5.5	1.5
2-6-1	15	34	30	1.3	1.7
2-6-2	15	36	30	1.2	1.5
2-6-3	15	38	32	2.7	3.0
2-6-4	15	38	34	4.9	1.3
3-6-1	15	32	28	1.2	1.9
3-6-2	15	35	30	1.8	1.3
3-6-3	15	36	30	3.2	1.4
3-6-4	15	38	32	4.2	1.6
4-6-1A	5	37	28	2.1	1.5
4-6-1B	9	41	28	3.6	1.1
4-6-2	15	43	34	2.9	2.0
4-6-3A	8	43	37	4.1	1.4
4-6-3B	7	42	35	2.4	1.8

Table 2
(continued)

Day-zone-occ	N	Ambient	Chg T avg©	Chg T range©	MV std dev
5-6-1	15	41	32	2.2	1.1
5-6-2	15	42	33	2.7	1.2
5-6-3	15	43	37	5.5	1.7
5-6-4	15	44	40	7.1	1.5
6-6-1	8	40	34	1.2	1.1
6-6-2	7	43	34	1.5	1.1
6-6-3	6	44	40	1.2	0.4
7-6-1	15	32	28	1.6	1.5
7-6-2	15	33	29	1.1	1.6
7-6-3	15	34	31	2.9	1.2
7-6-4	15	36	35	9.3	1.4
7-6-5	15	38	32	3.7	0.7
8-6-1	15	44	37	6.3	1.7
9-6-1	15	36	27	2.1	0.7
9-6-2	15	39	29	0.9	0.9
9-6-3	15	42	32	1.9	1.4
10-6-1	15	37	27	2.2	1.1
10-6-2	15	39	29	1.6	1.1
10-6-3	15	41	31	5.1	0.8
10-6-4	15	42	35	6.9	1.1

The velocity standard deviation as a result of the uncontrolled temperature conditioning of the charges was plotted to visualize any degradation in precision (muzzle velocity uniformity) as a function of temperature variability within the test group. The data shows that the velocity standard deviation does not correlate well with temperature variability concluding that the effect of temperature variation is not as significant as predicted by prior studies based on bag charge performance. In fact, the effect was so small that it could not be measured because of other system errors (fig. 4).

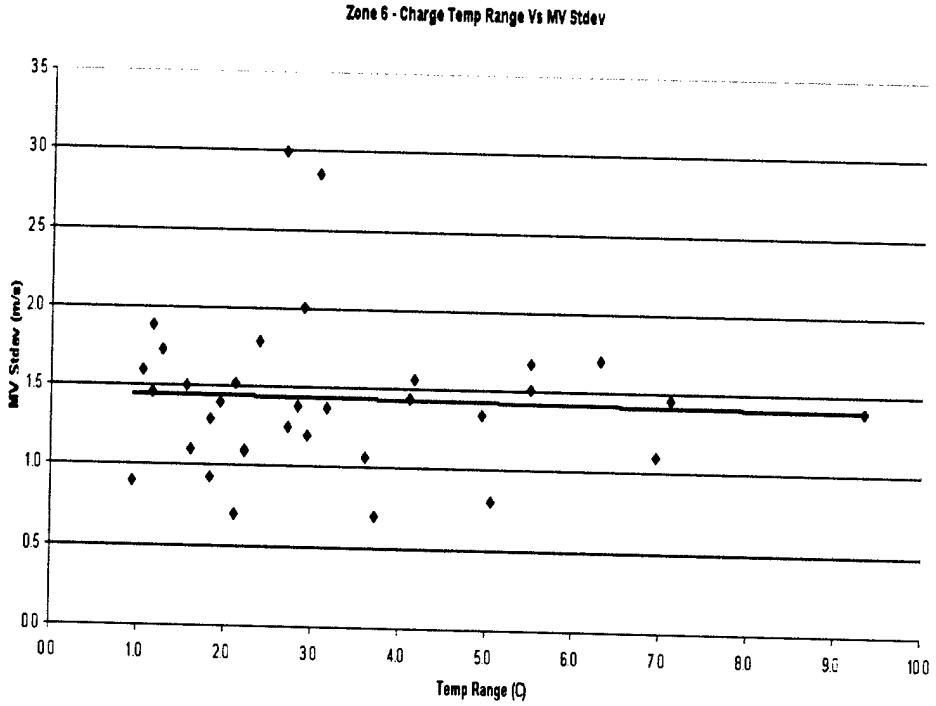


Figure 4
Zone 6 – charge temperature range versus muzzle velocity standard deviation

Summary

The temperature distribution of a pallet of MACS increments that have been exposed to the desert conditions for more than 24 hrs at the conditions that occurred during the test at Yuma Proving Ground consistently exhibit a low temperature variation (<10°C) between increments. Pallets of charges subjected to high solar radiation should yield the largest expected temperature variation between charges subjected to the same air temperature. In these tests, the temperature standard deviation of the test groups ranged from 0.3°C to 3.3°C, the average being 1.1°C. It should also be noted that for the one occasion where the temperature standard deviation was the largest (3.3°C), the resulting muzzle velocity standard deviation was less than 2.0 m/s. The appendix has details of the test data and analysis.

CONCLUSION

Charges from pallets stored at the same site where the air temperature is somewhat uniform and that are immediately loaded and fired can be expected to perform satisfactorily with regards to muzzle velocity standard deviation (precision). Subjecting unprotected pallets of charges to prevailing desert conditions without cover showed no adverse impact on precision.

The results of this testing shows that a temperature management system to record individual increment temperatures and any attempt to correct aiming data, based on the individual temperatures, would not result in any improvement in precision when the temperature range is less than 10°C under the scenario used in the test.

The current application of adjusting aiming data for average powder temperature should be continued and not expanded to individual charge temperatures unless firing scenarios are validated where temperature range in charges would exceed 10°C. Should such scenarios be identified, further testing similar to that described in this report would be recommended prior to implementing an individual charge temperature management system.

APPENDIX

TEST DATA AND ANALYSIS

The "test group" was composed of five pallets for a total of 750 MACS M232 propellant charges. PA103A2 containers were numbered 1 through 30 starting from the top left corner and working across starting with the first pallet then 31 to 60 for the second pallet and so forth.

Test Setup

The test group pallets were subjected to the Yuma Proving Grounds (YPG) natural environment for a minimum of 24 hrs. The lid end of the pallet for the test group faced the south/south-west end. The control groups were conditioned in a conditioning chamber for 24 hrs minimum at 21°C.

In addition to test and control pallets, a pallet of M232 charges was called the "shadow group." The shadow group contained 14 MACS Increment Thermal Emulators (ITEs). The ITEs were inert charges developed specifically to emulate the thermal characteristics of a live M232 charge. Embedded within the ITE is temperature sensing and recording instrumentation. Each ITE records temperature data real time that can be later downloaded via a personal computer. The shadow group was subjected to the same environment as the test charges. The 14 ITE's replaced the charges as follows in the pallet, where A represents the lid end of the can, C represents the middle charge, and E represents the base end of the can (fig. A1). An additional ITE was placed on top of the pallet to record the temperature effect due to solar radiation and insulation provided by the can.

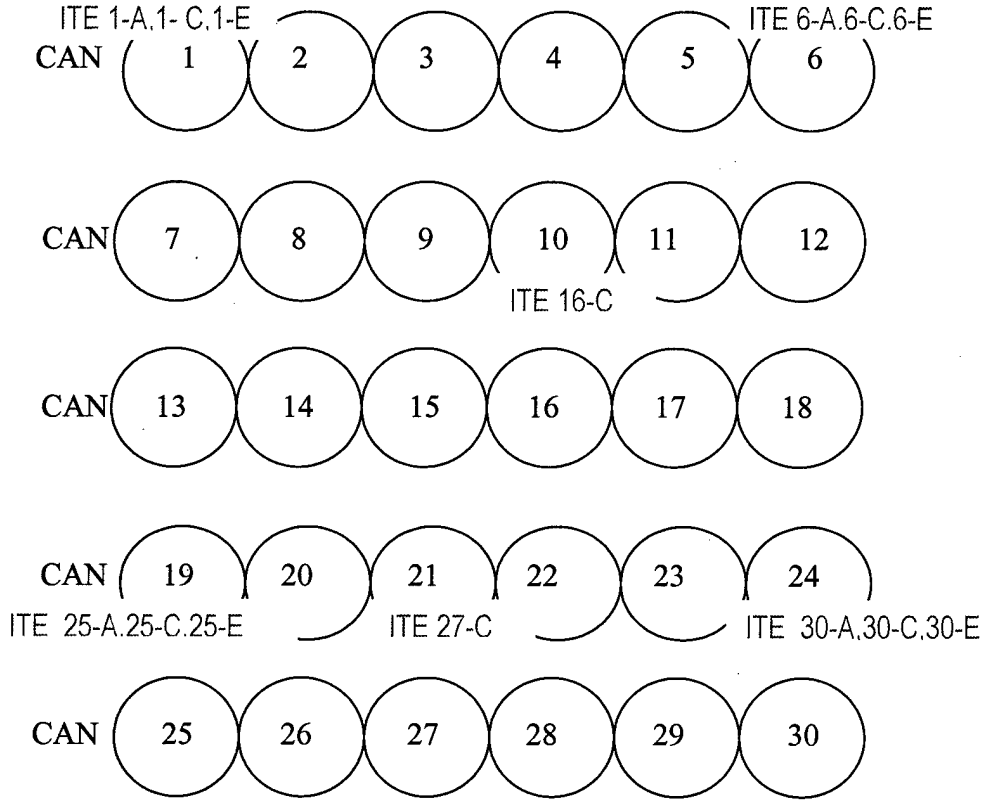
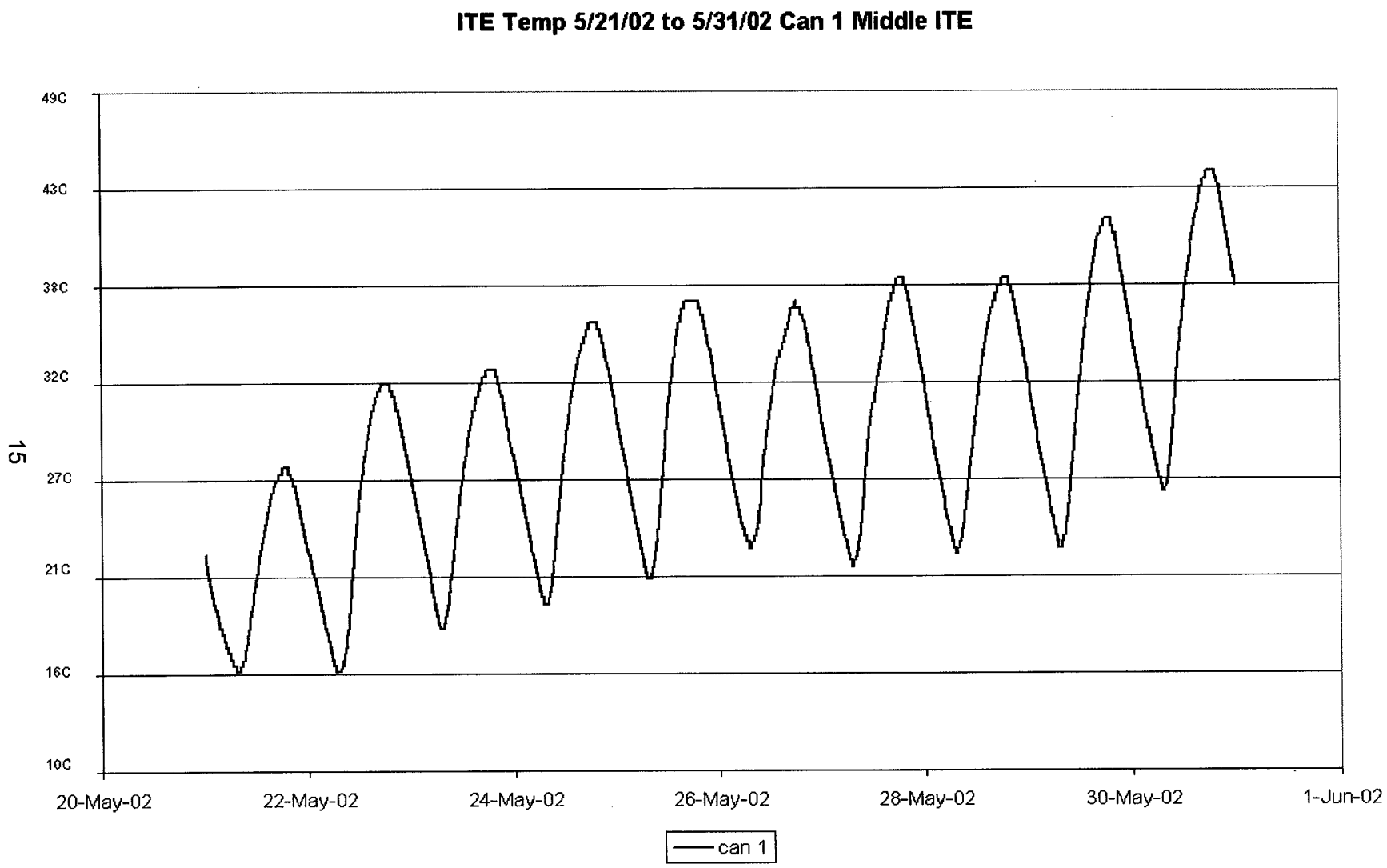
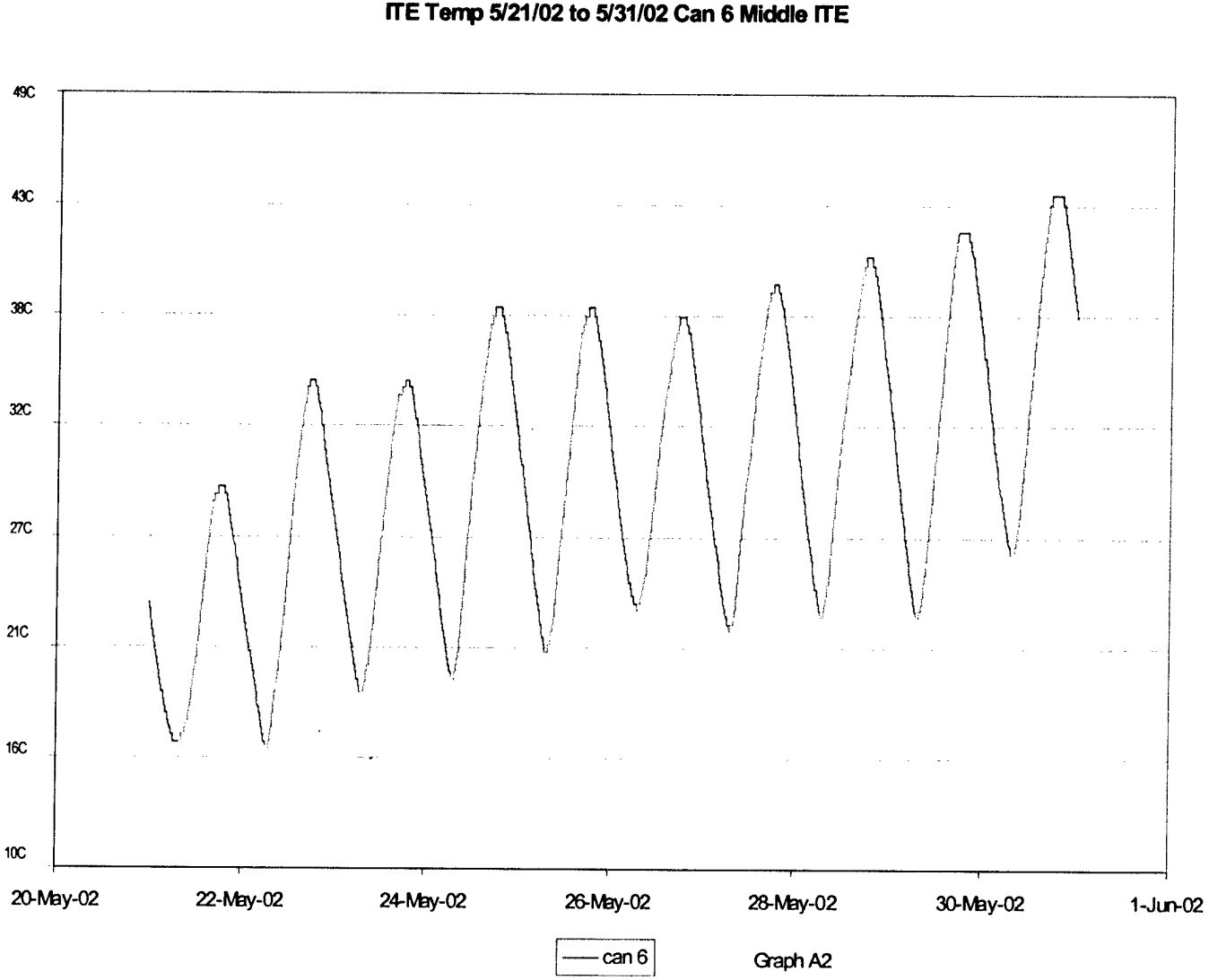


Figure A1
ITE replacements

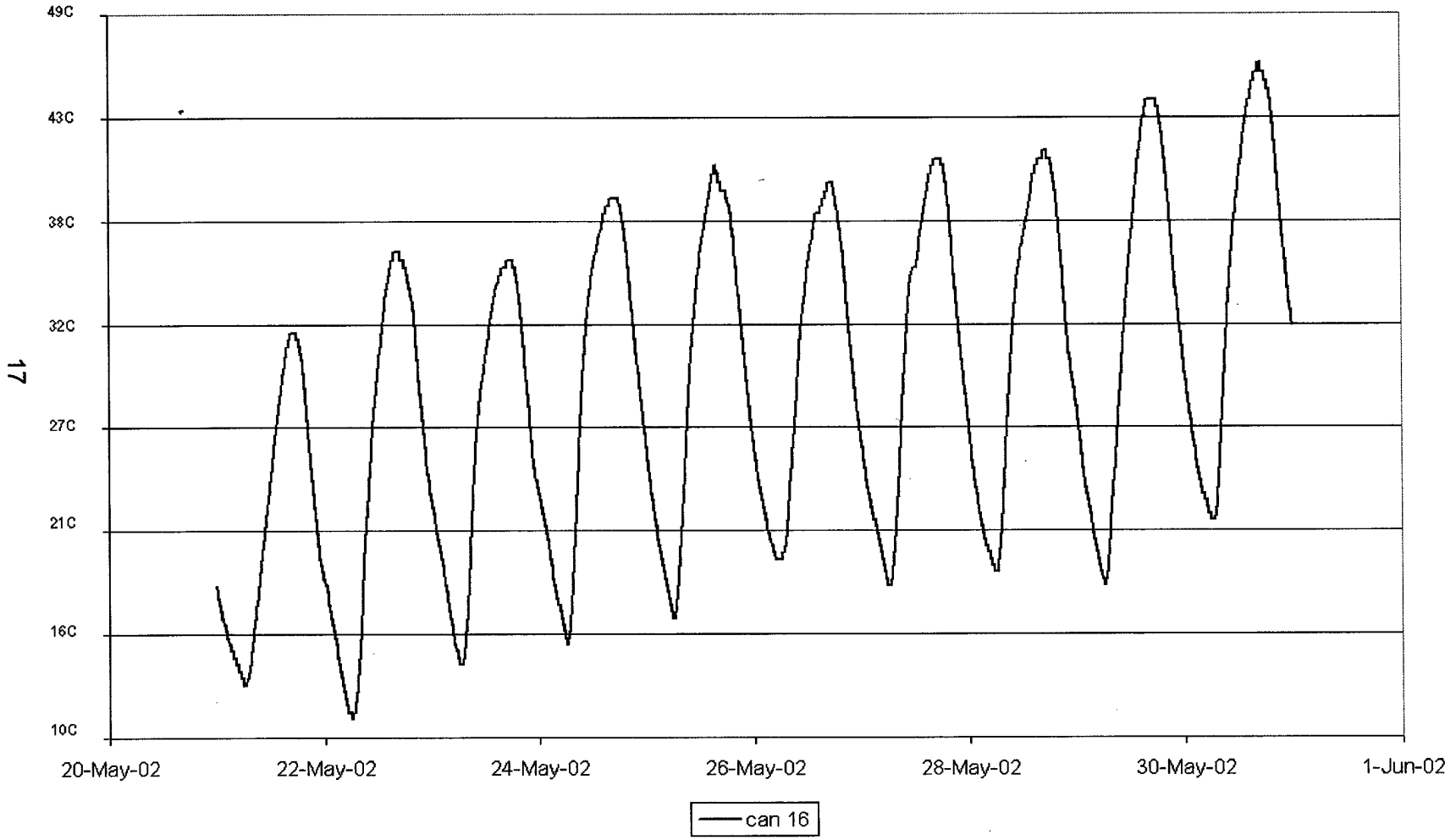
The temperature data from the middle ITE for each can with an instrumented charge and the ITE placed on top of the pallet during the time frame of May 21st to May 31st where Phase 1 firings occurred are presented (graphs A1 to A7). Additionally, the delta between the highest recorded ITE temperature and lowest recorded ITE temperature at each time is plotted to present the temperature extremes within a pallet of charges at a particular time (graph A8).


ITE Temp 5/21/02 to 5/31/02 Can 1 Middle ITE
49C
43C
38C
32C
27C
21C
16C
10C
15
20-May-02
22-May-02
24-May-02
26-May-02
28-May-02
30-May-02
1-Jun-02
can 1

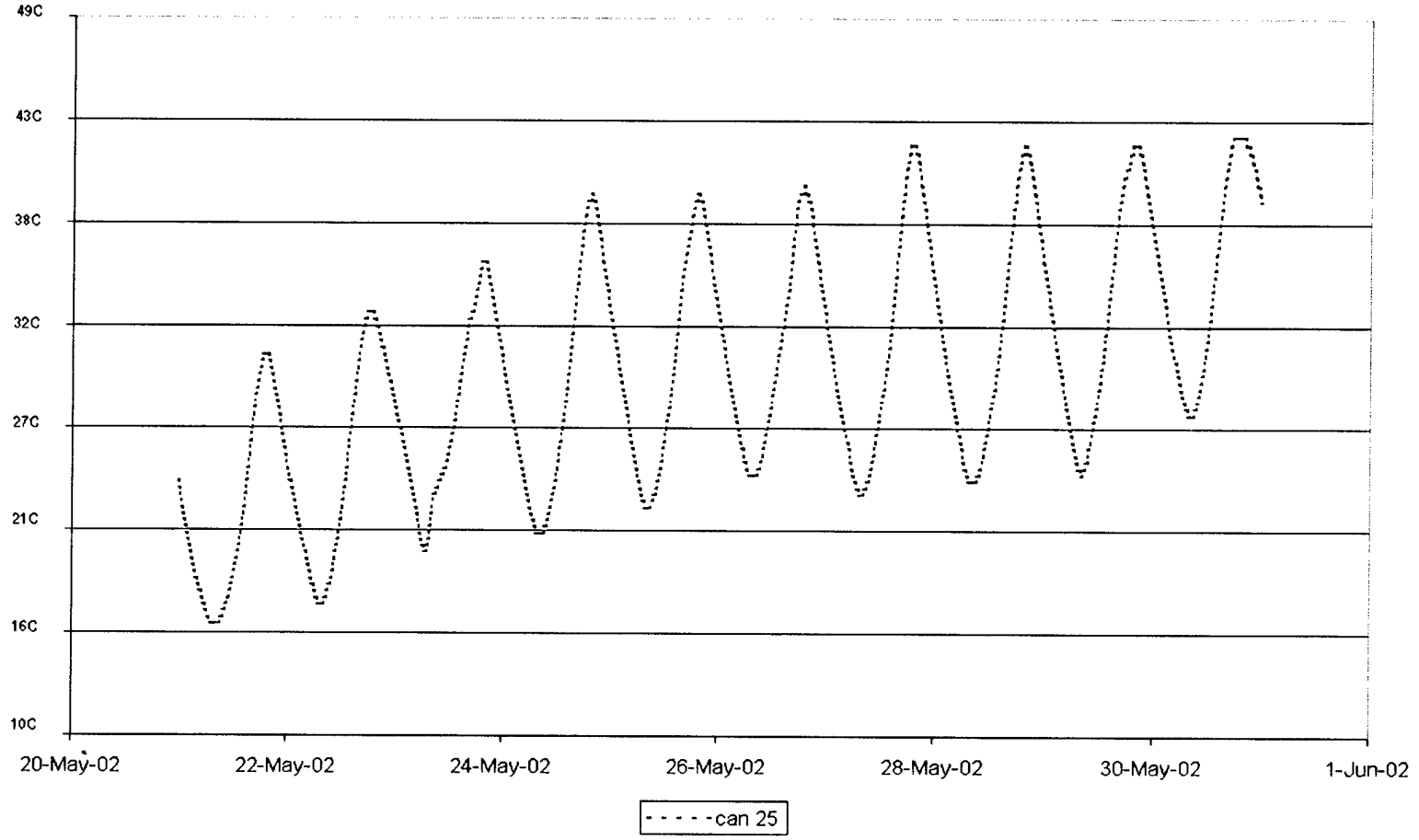
Graph A1


ITE Temp 5/21/02 to 5/31/02 Can 6 Middle ITE
49C
43C
38C
32C
27C
21C
16C
10C
20-May-02
22-May-02
24-May-02
26-May-02
28-May-02
30-May-02
1-Jun-02
can 6
Graph A2

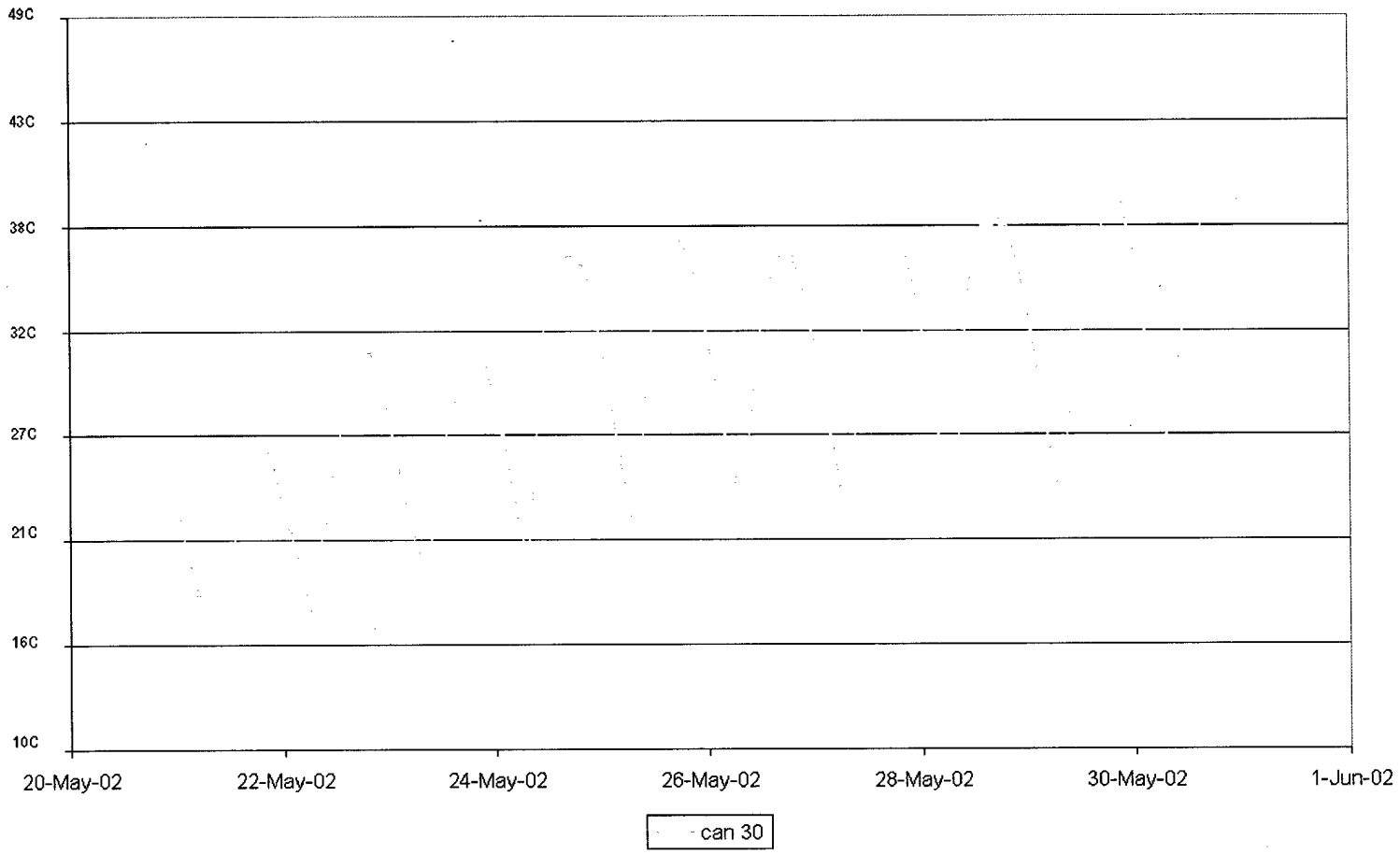
Graph A2


ITE Temp 5/21/02 to 5/31/02 Can 16 Middle ITE
49C
43C
38C
32C
27C
21C
16C
10C
17
20-May-02
22-May-02
24-May-02
26-May-02
28-May-02
30-May-02
1-Jun-02
can 16

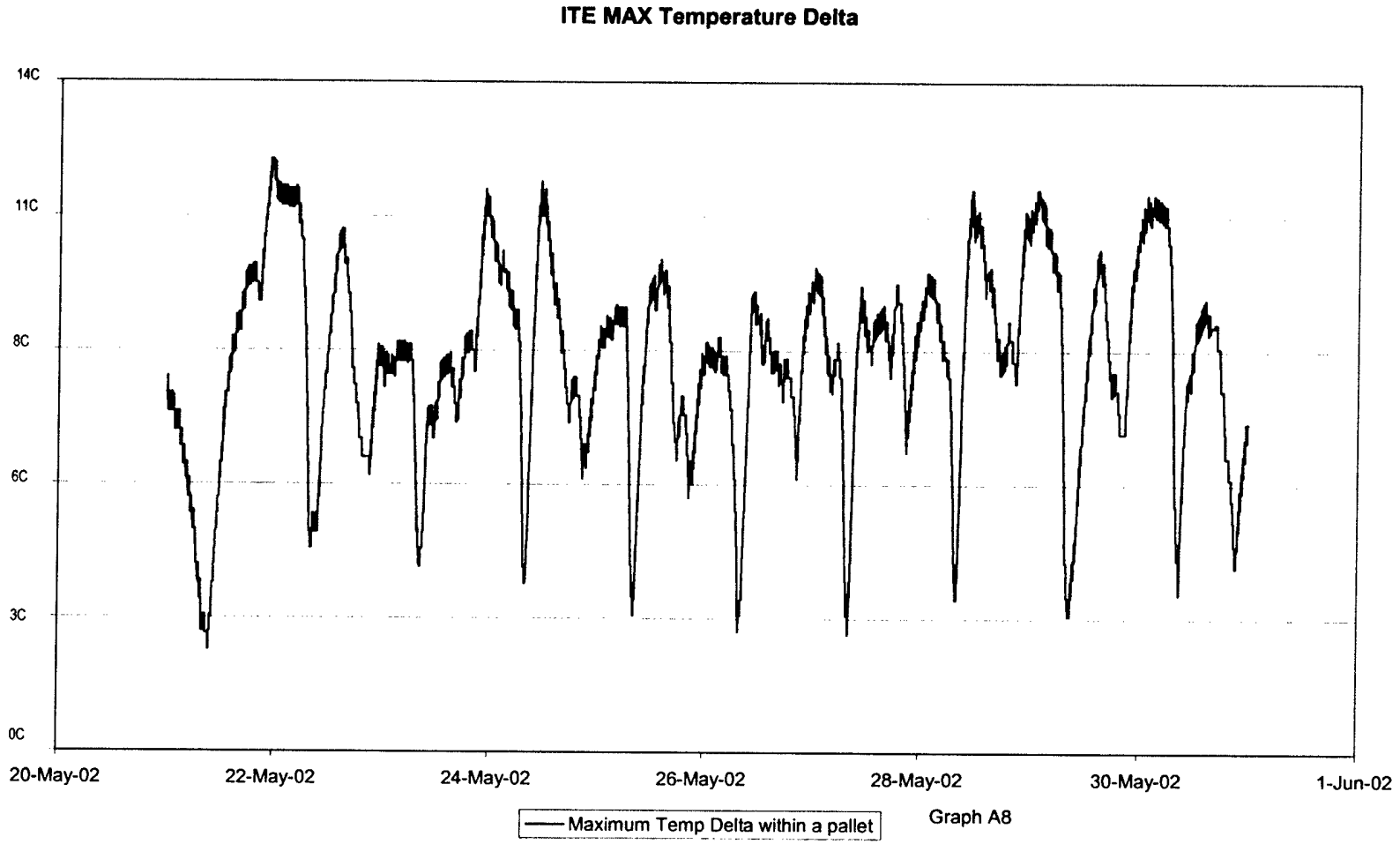
Graph A3


ITE Temp 5/21/02 to 5/31/02 Can 25 Middle ITE
49C
43C
38C
32C
27C
21C
16C
10C
20-May-02
22-May-02
24-May-02
26-May-02
28-May-02
30-May-02
1-Jun-02
can 25

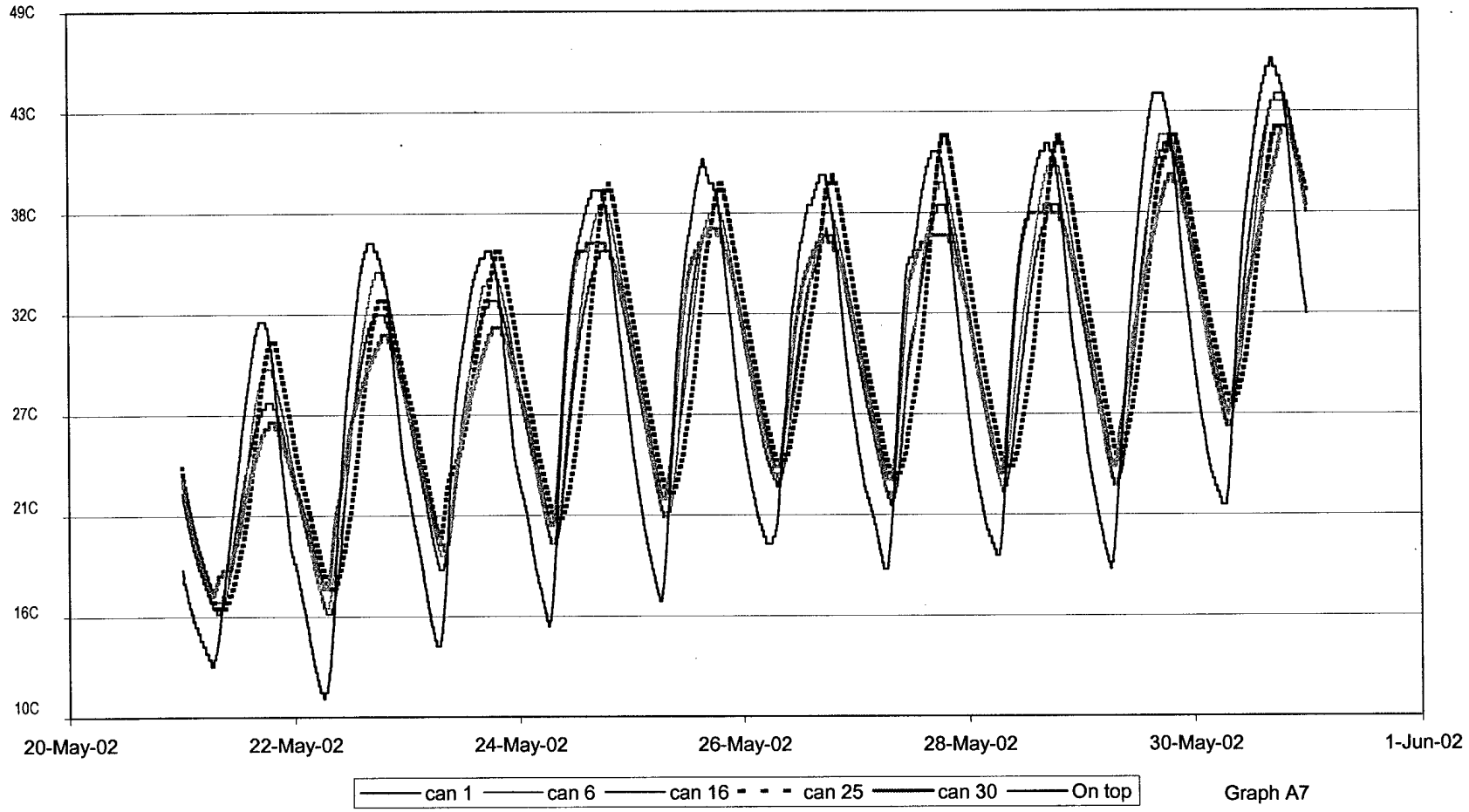
Graph A4


ITE Temp 5/21/02 to 5/31/02 Can 30 Middle ITE
49C
43C
38C
32C
27C
21C
16C
10C
20-May-02
22-May-02
24-May-02
26-May-02
28-May-02
30-May-02
1-Jun-02
can 30

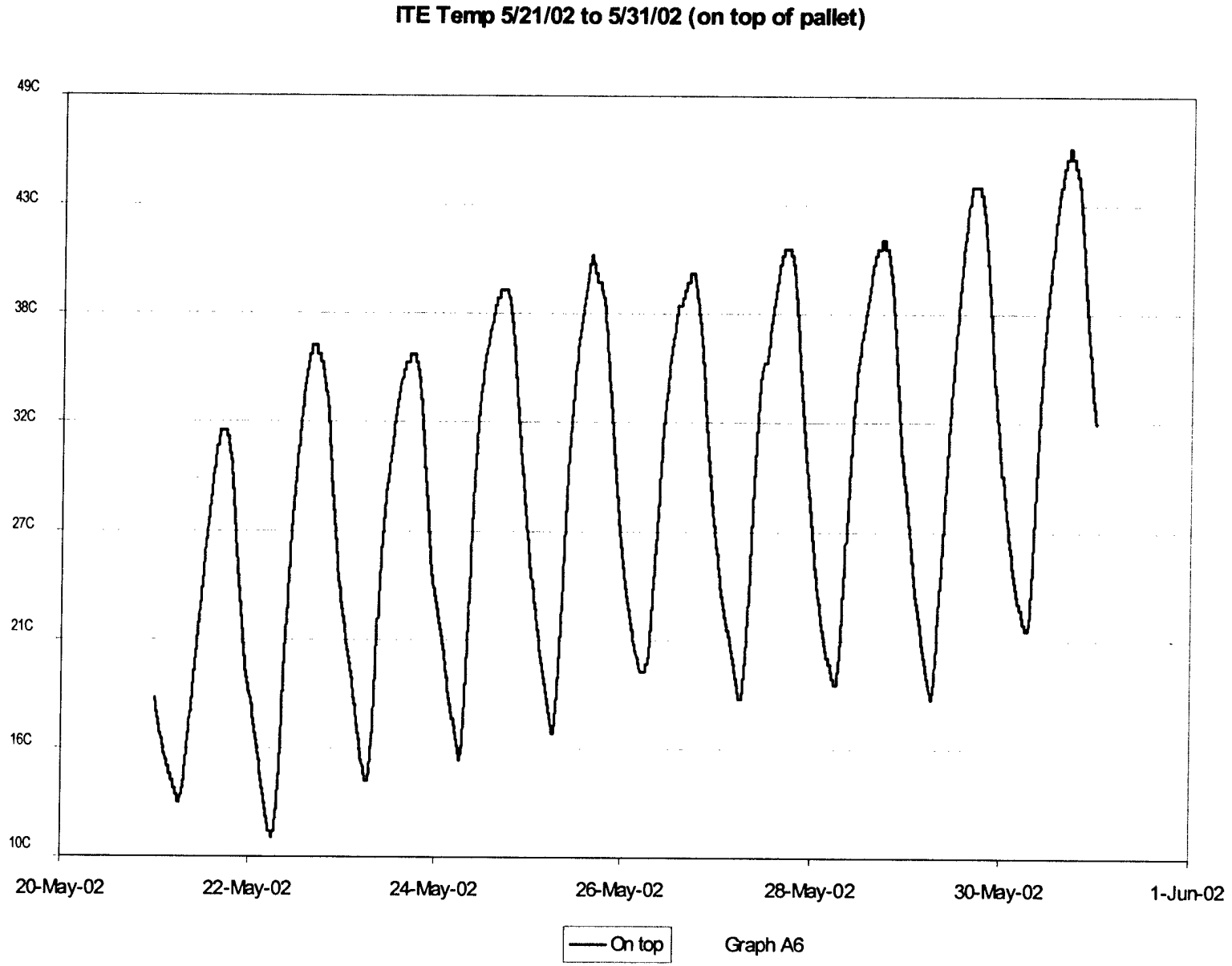
Graph A5


ITE MAX Temperature Delta
14C
11C
8C
6C
3C
0C
20-May-02
22-May-02
24-May-02
26-May-02
28-May-02
30-May-02
1-Jun-02
Maximum Temp Delta within a pallet
Graph A8

Graph A6


ITE Temp 5/21/02 to 5/31/02
49C
43C
38C
32C
27C
21C
16C
10C
20-May-02
22-May-02
24-May-02
26-May-02
28-May-02
30-May-02
1-Jun-02
can 1
can 6
can 16
can 25
can 30
On top
Graph A7

Graph A7


ITE Temp 5/21/02 to 5/31/02 (on top of pallet)
49C
43C
38C
32C
27C
21C
16C
10C
20-May-02
22-May-02
24-May-02
26-May-02
28-May-02
30-May-02
1-Jun-02
On top
Graph A6

Graph A8

The firing data from phase 1 and phase 2 is summarized here.

- For each occasion, the test group charges were selected from a cross-section of cans across the entire pallet to minimize the uniformity in ambient temperature conditioning. For example, Occasion 3-1, charges from cans 1, 8, 15, 22, 27, and 29 were selected from the pallet.

- To determine the temperature variation within a group of charges, the center core temperature of a sample of charges from each group was measured. For example, Occasion 3-1, temperature data of the first, middle, and end charge of can 1 and the middle charge of can 27 were collected.

- To determine the effect of temperature on muzzle velocity (MV) for an individual round within a group, the average muzzle velocity for each group was calculated. The deviation of the MV for the individual round from the average MV was calculated and presented in the following tables. For phase 1, similar calculations are presented for the control groups.

- The graphs show the deviation of the individual MV from the average MV.

- Additionally, for each group, the mean absolute deviation (MAD) was calculated and presented at the bottom of each table.

$$MAD = \frac{\sum |X - u|}{N}$$

where $\Sigma |X-\mu|$ is the sum of the absolute differences between each observed sample value, X and the sample mean μ, while N is the number of observations in the sample.

- No difference was noted in the mean absolute deviation between the test and control groups for phase 1.

Phase 1

Zone 3 - Occasion 1

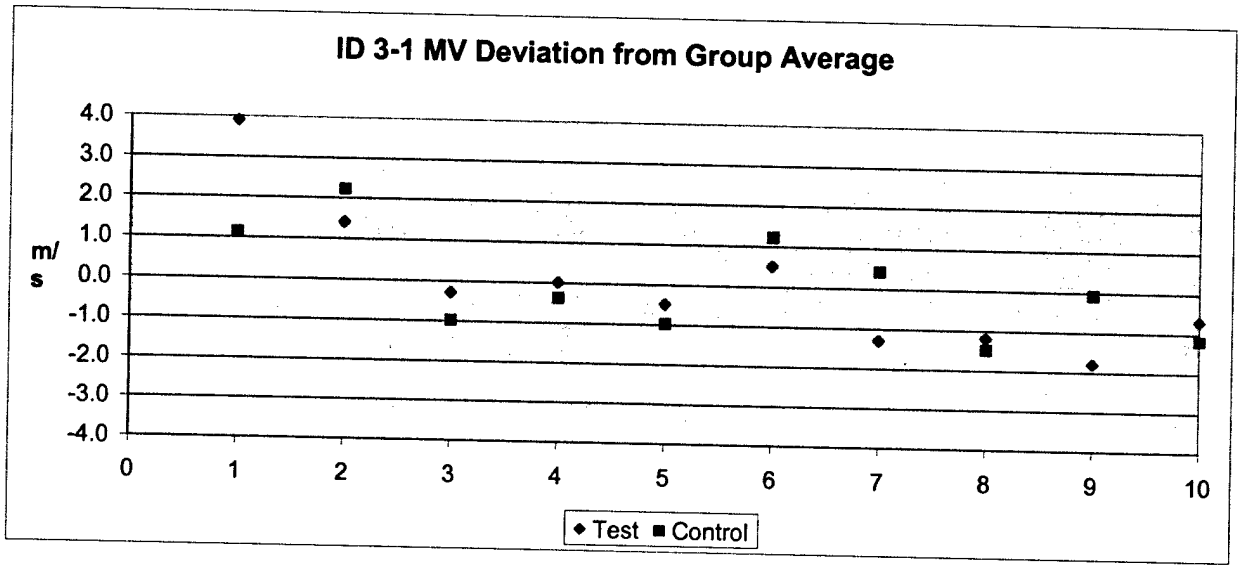
Test Group

SPH Round #	Can #		Ind Vel - Avg Vel of Group
6324	1	596.3	3.9
6325	8	593.8	1.4
6326	15	592.1	-0.3
6327	22	592.4	0.0
6328	27	591.9	-0.5
6329	29	592.9	0.5
6330		591.1	-1.3
6331		591.2	-1.2
6332		590.6	-1.8
6333		591.7	-0.7
MAD			1.2

Charge ID for Temperature Measurement	Sampled Increments Temp ©
1A	20.7
1C	19.8
1E	20.0
27C	18.2

Control Group

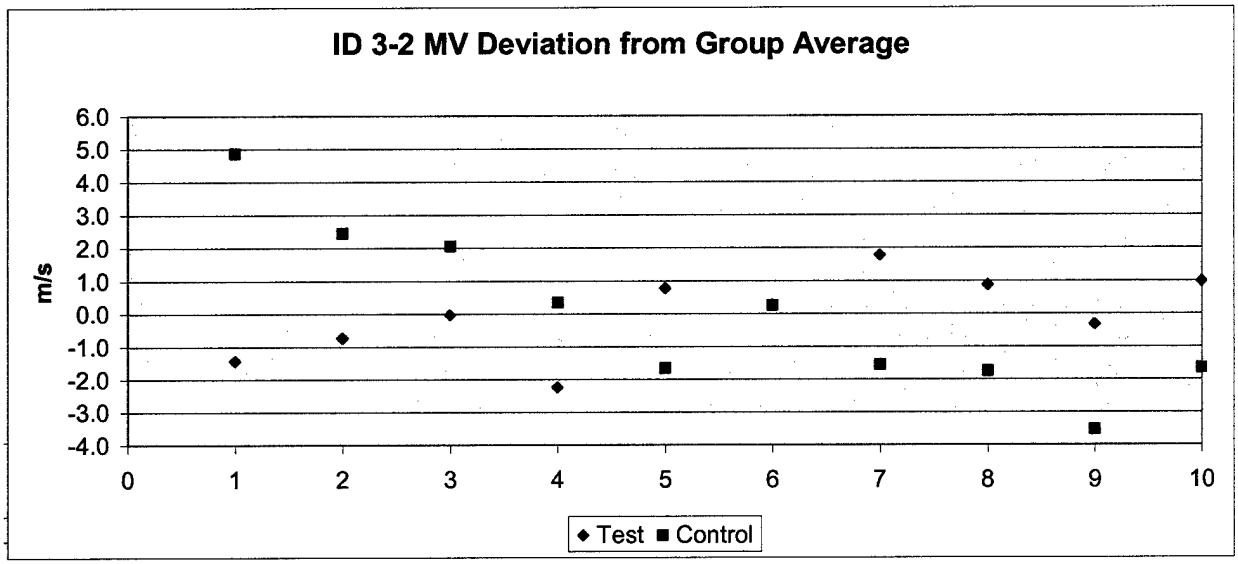
6334			1.1
6335			2.2
6336			-1.0
6337			-0.4
6338			-1.0
6339			1.2
6340			0.4
6341			-1.5
6342			-0.1
6343			-1.2
MAD			1.0



Zone 3 - Occasion 2

SPH Round #	Can #		Ind Vel - Avg Vel of Group
Test Group			
6393	3	589.8	-1.4
6394	8	590.5	-0.7
6395	15	591.2	0.0
6396	22	589.0	-2.2
6397	26	592.0	0.8
6398	30	591.5	0.3
6399		593.0	1.8
6400		592.1	0.9
6401		590.9	-0.3
6402		592.2	1.0
MAD			0.9
Control Group			
6383			4.9
6384			2.5
6385			2.1
6386			0.4
6387			-1.6
6388			0.3
6389			-1.5
6390			-1.7
6391			-3.5
6392			-1.6
MAD			2.0

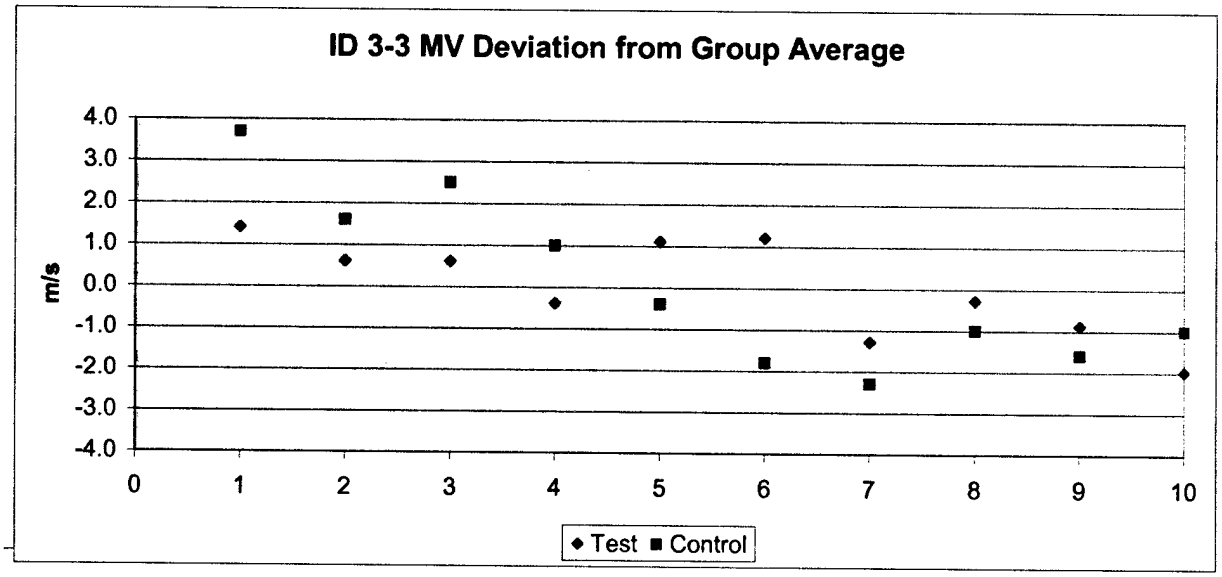
Charge ID for Temperature Measurement	Sampled Increments Temp ©
30A	28.3
30B	27.8
30C	28.8



Zone 3 - Occasion 3

SPH Round #	Can #		Ind Vel - Avg Vel of Group
Test Group			
6473	3	593.3	1.4
6474	6	592.5	0.6
6475	15	592.5	0.6
6476	22	591.5	-0.4
6477	26	593.0	1.1
6478	29	593.1	1.2
6479		590.6	-1.3
6480		591.6	-0.3
6481		591.0	-0.9
6482		589.9	-2.0
MAD			1.0
Control Group			
6463			3.7
6464			1.6
6465			2.5
6466			1.0
6467			-0.4
6468			-1.8
6469			-2.3
6470			-1.0
6471			-1.6
6472			-1.0
MAD			1.7

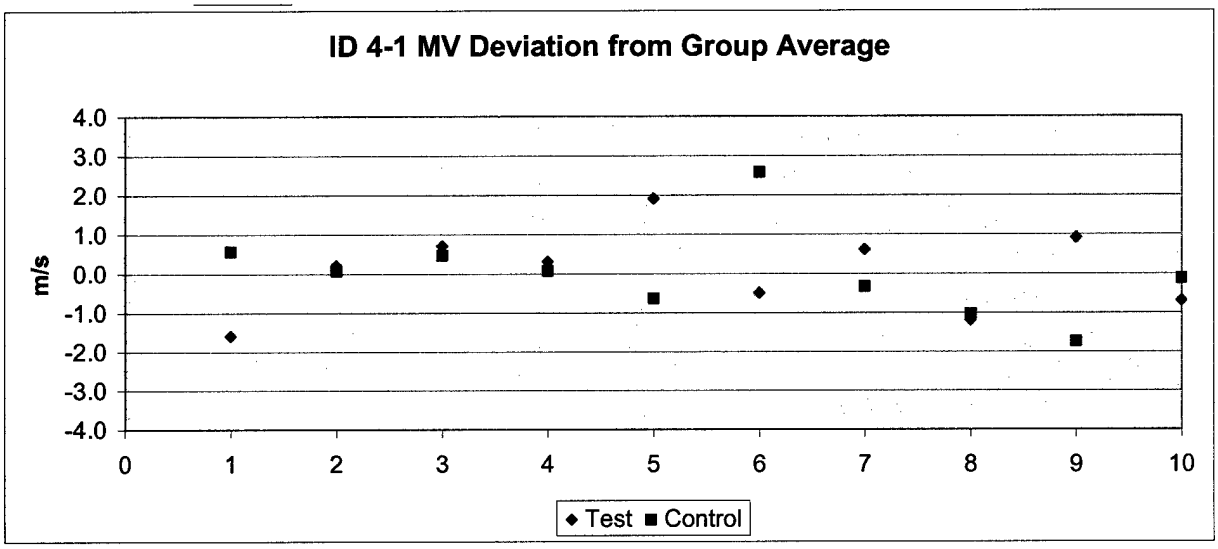
Charge ID for Temperature Measurement	Sampled Increments Temp ©
6A	40.9
6C	39.9
6E	39.6



Zone 4 - Occasion 1

SPH Round #	Can #		Ind Vel - Avg Vel of Group
Test Group			
6344	2	721.0	-1.6
6345	5	722.8	0.2
6346	9	723.3	0.7
6347	13	722.9	0.3
6348	16	724.5	1.9
6349	23	722.1	-0.5
6350	26	723.2	0.6
6351	30	721.4	-1.2
6352		723.5	0.9
6353		721.9	-0.7
MAD			0.9
Control Group			
6354			0.6
6355			0.1
6356			0.5
6357			0.1
6358			-0.6
6359			2.6
6360			-0.3
6361			-1.0
6362			-1.7
6363			-0.1
MAD			0.8

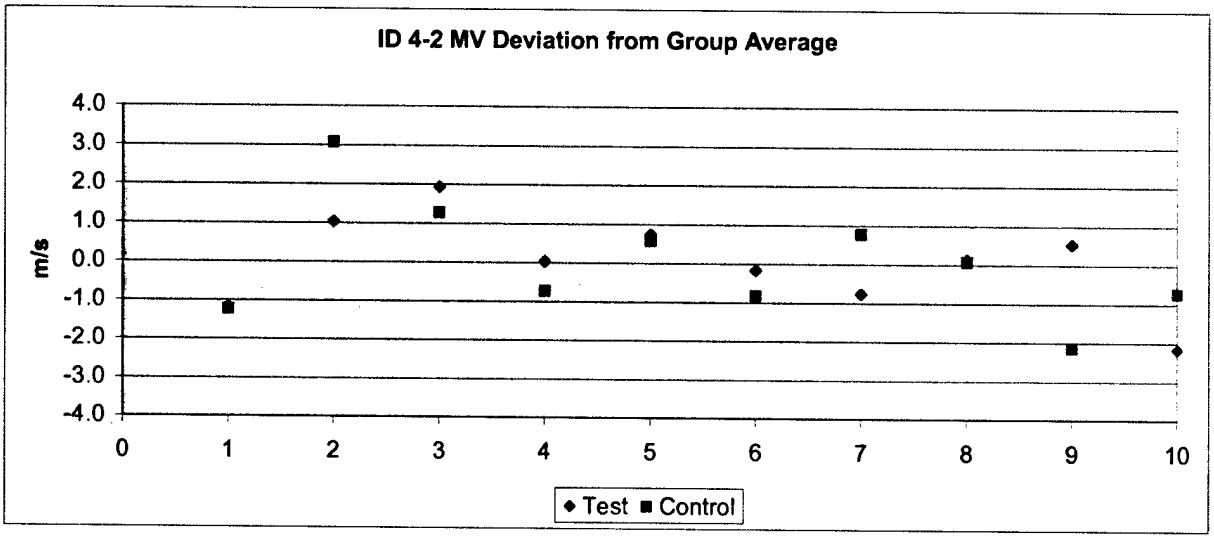
Charge ID for Temperature Measurement	Sampled Increments Temp ©
16C	22.4
30A	27.8
30B	26.4
30C	28.3



Zone 4 - Occasion 2

SPH Round #	Can #		Ind Vel - Avg Vel of Group
Test Group			
6413	1	719.4	-1.2
6414	2	721.6	1.0
6415	5	722.5	1.9
6416	9	720.6	0.0
6417	13	721.3	0.7
6418	18	720.4	-0.2
6419	23	719.8	-0.8
6420	27	720.7	0.1
6421		721.1	0.5
6422		718.4	-2.2
MAD			0.9
Control Group			
6403			-1.2
6404			3.1
6405			1.3
6406			-0.7
6407			0.6
6408			-0.8
6409			0.8
6410			0.1
6411			-2.1
6412			-0.7
MAD			1.1

Charge ID for Temperature Measurement	Sampled Increments Temp ©
1A	28.8
1C	28.6
1E	29.2
27C	28.9



Zone 5 - Occasion 1

SPH Round #	Can #		Ind Vel - Avg Vel of Group

Charge ID for Temperature Measurement	Sampled Increments Temp ©

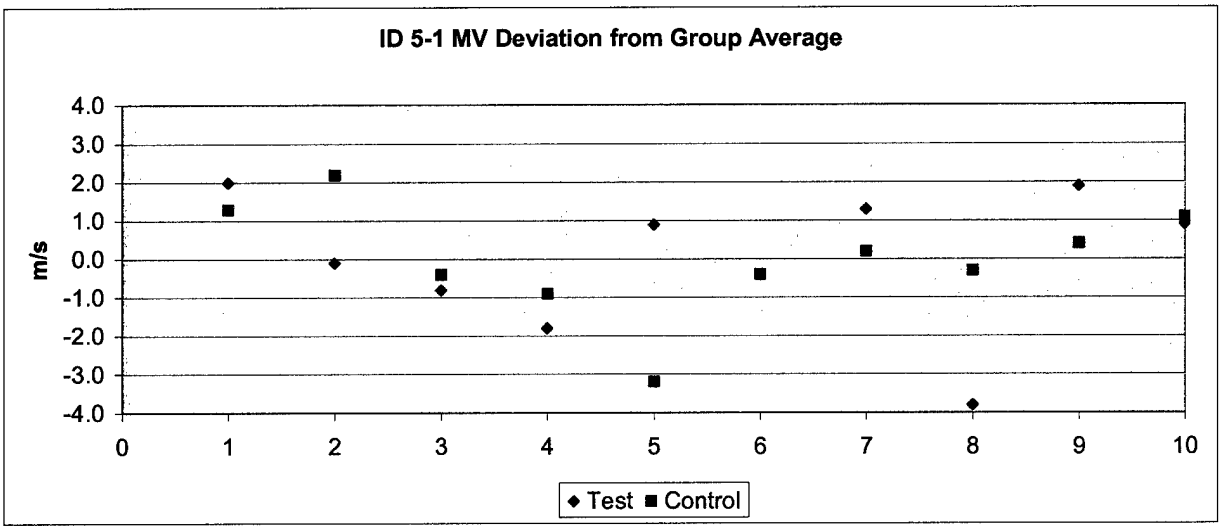
Test Group

6364	3	848.9	2.0
6365	6	846.8	-0.1
6366	10	846.1	-0.8
6367	12	845.1	-1.8
6368	14	847.8	0.9
6369	18	846.5	-0.4
6370	19	848.2	1.3
6371	21	843.1	-3.8
6372	24	848.8	1.9
6373	28	847.8	0.9
MAD			1.4

6A	30.7
6C	29.4
6E	29.7

Control Group

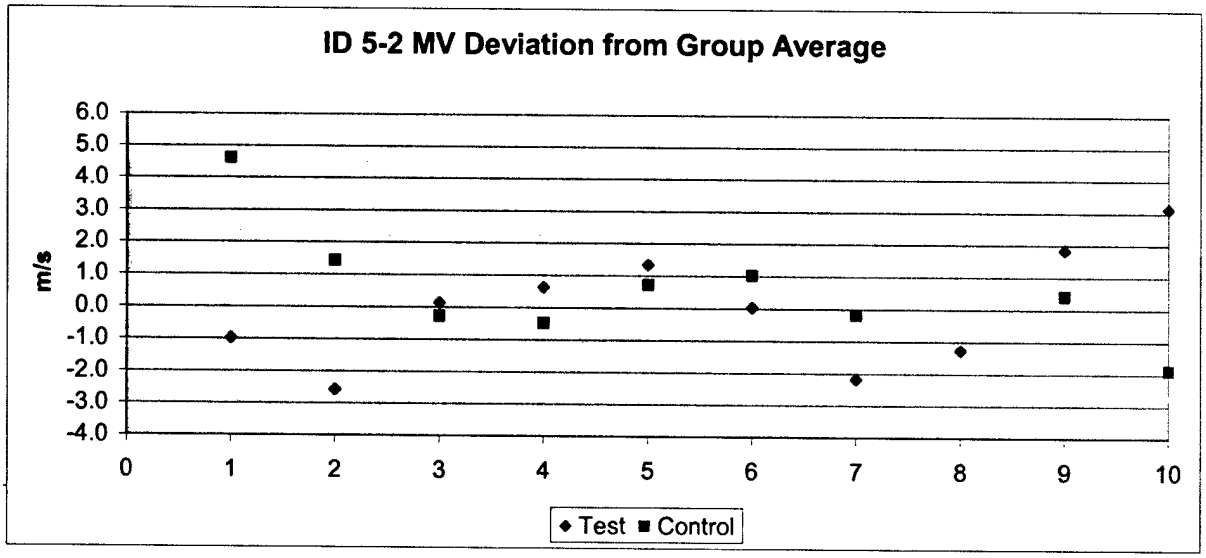
6374			1.3
6375			2.2
6376			-0.4
6377			-0.9
6378			-3.2
6379			-0.4
6380			0.2
6381			-0.3
6382			0.4
6383			1.1
MAD			1.0



Zone 5 - Occasion 2

SPH Round #	Can #		Ind Vel - Avg Vel of Group
Test Group			
6453	7	848.3	-1.0
6454	10	846.7	-2.6
6455	12	849.4	0.1
6456	14	849.9	0.6
6457	19	850.6	1.3
6458	21	849.3	0.0
6459	24	847.1	-2.2
6460	25	848.0	-1.3
6461	28	851.1	1.8
6462	29	852.4	3.1
MAD			1.4
Control Group			
6463			4.6
6464			1.4
6465			-0.3
6466			-0.5
6467			0.7
6468			1.0
6469			-0.2
6470			-5.3
6471			0.4
6472			-1.9
MAD			1.6

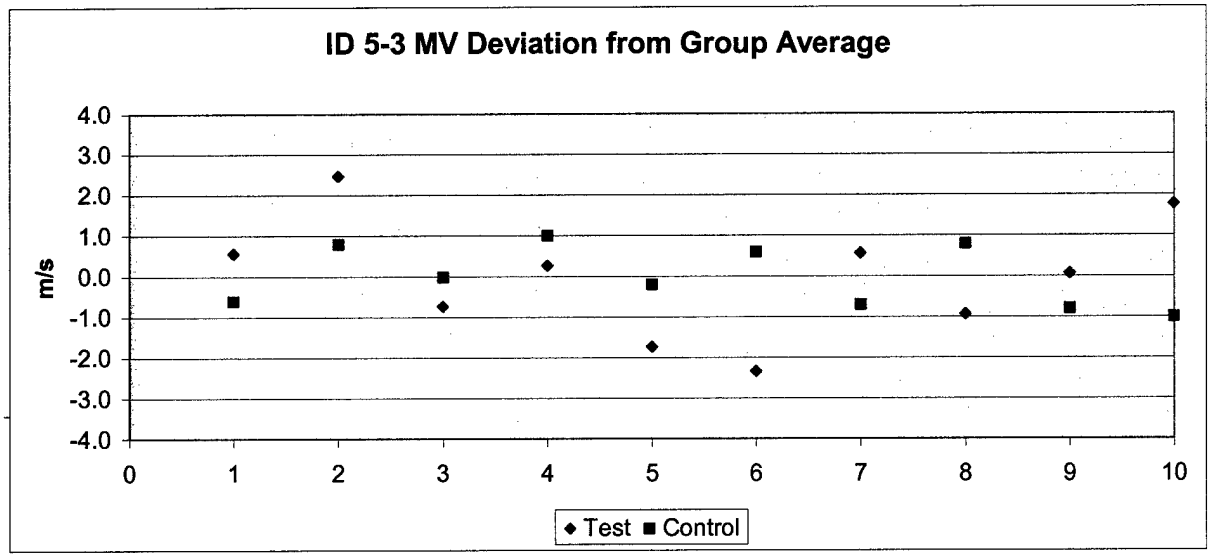
Charge ID for Temperature Measurement	Sampled Increments Temp ©
25A	36.8
25C	35.1
25E	36.1



Zone 5 - Occasion 3

SPH Round #	Can #		Ind Vel - Avg Vel of Group
Test Group			
6413	1	851.8	0.6
6414	8	853.7	2.5
6415	10	850.5	-0.7
6416	12	851.5	0.3
6417	14	849.5	-1.7
6418	17	848.9	-2.3
6419	19	851.8	0.6
6420	21	850.3	-0.9
6421	24	851.3	0.1
6422	30	853.0	1.8
MAD			1.1
Control Group			
6403			-0.6
6404			0.8
6405			lost
6406			1.0
6407			-0.2
6408			0.6
6409			-0.7
6410			0.8
6411			-0.8
6412			-1.0
MAD			0.6

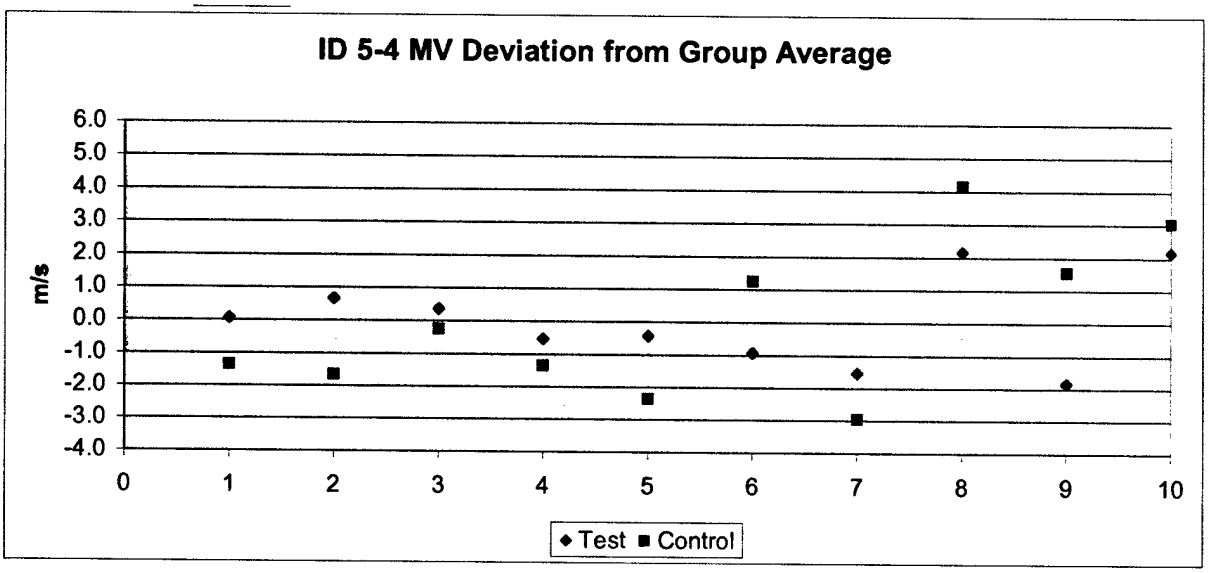
Charge ID for Temperature Measurement	Sampled Increments Temp ©
1A	37.4
1C	36.2
1E	36.9
30A	39.6
30C	38.1
30E	37.4



Zone 5 - Occasion 4

SPH Round #	Can #		Ind Vel - Avg Vel of Group
Test Group			
6264	1	846.7	0.1
6265	5	847.3	0.6
6266	8	847.0	0.4
6267	10	846.1	-0.5
6268	15	846.2	-0.4
6269	17	845.7	-0.9
6270	20	845.1	-1.5
6271	24	848.8	2.1
6272	27	844.8	-1.9
6273	30	848.8	2.1
MAD			1.1
Control Group			
6274			-1.4
6275			-1.7
6276			-0.3
6277			-1.4
6278			-2.4
6279			1.2
6280			-3.0
6281			4.1
6282			1.5
6283			3.0
MAD			2.0

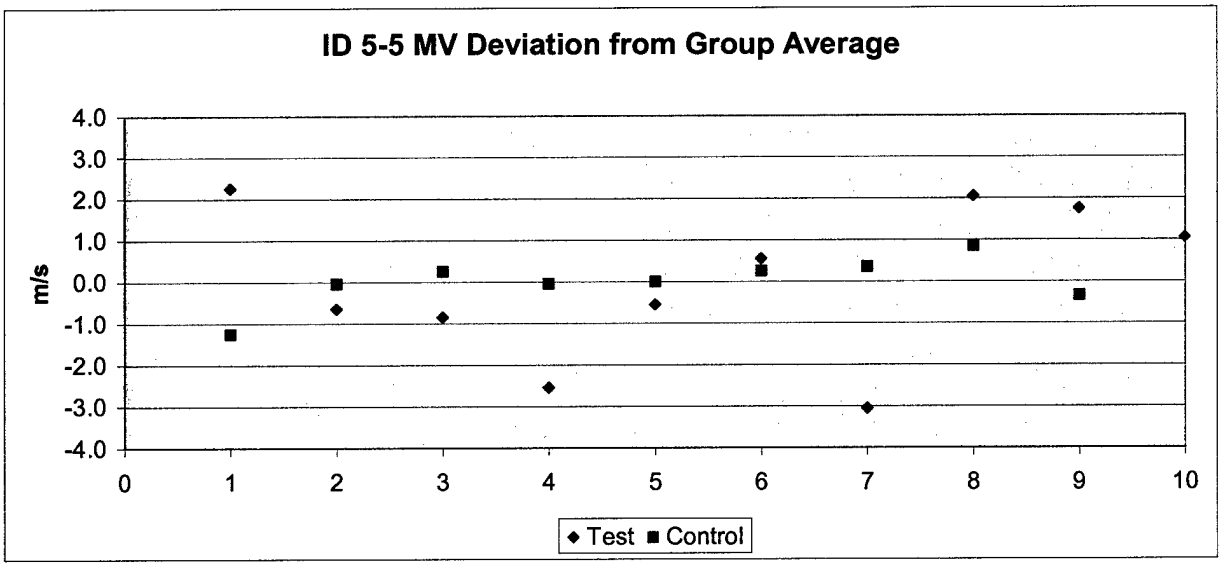
Charge ID for Temperature Measurement	Sampled Increments Temp ©
1A	22.9
1C	22.6
1E	22.4
27C	22.7
30A	25.4
30C	24.8
30E	25.3



Zone 5 - Occasion 5

SPH Round #	Can #		Ind Vel - Avg Vel of Group
Test Group			
6373	2	850.7	2.3
6374	6	847.8	-0.7
6375	7	847.6	-0.9
6376	11	845.9	-2.6
6377	14	847.9	-0.6
6378	18	849.0	0.5
6379	20	845.4	-3.1
6380	22	850.5	2.0
6381	25	850.2	1.8
6382	29	849.5	1.0
MAD			1.5
Control Group			
6363			-1.3
6364			-0.1
6365			0.3
6366			-0.1
6367			lost
6368			0.3
6369			0.4
6370			0.9
6371			-0.4
6372			
MAD			0.4

Charge ID for Temperature Measurement	Sampled Increments Temp ©
6A	34.2
6C	32.7
6E	32.1
25A	35.1
25C	30.7
25E	30.5



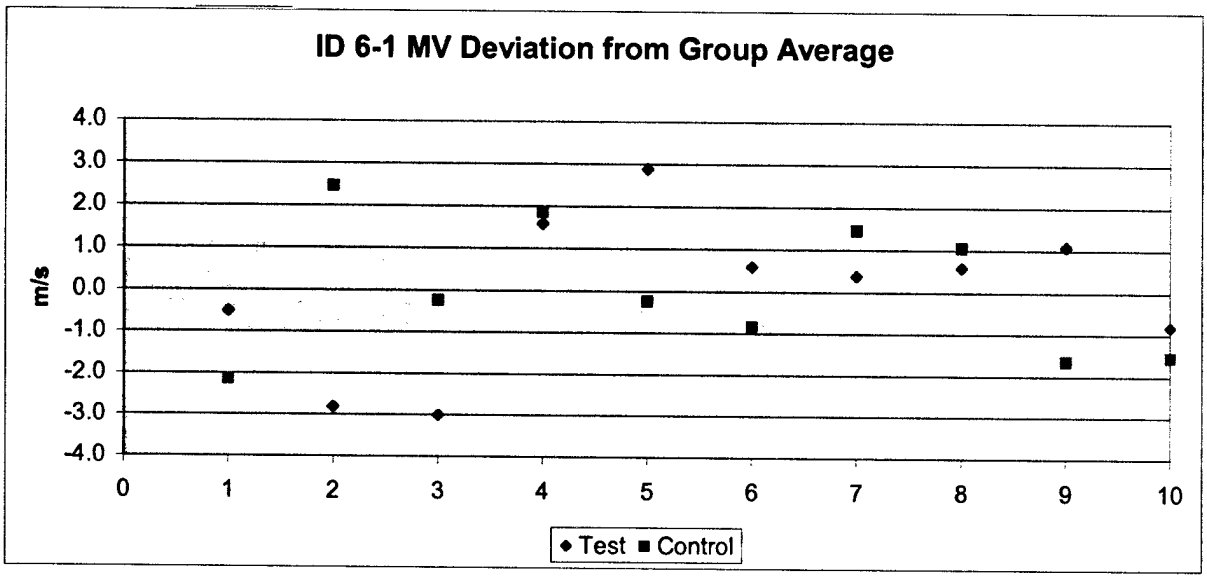
Zone 6 - Occasion 1

SPH Round #	Can #		Ind Vel - Avg Vel of Group
Test Group		Note: For Zone 6, charges were taken from two pallets, therefore in the cans are identified as 1-4 for Pallet 1 Can 4 and 2-6 for Pallet 2 Can 6	
6533	1-4	966 5	-0.5
6534	1-7	964 2	-2.8
6535	1-11	964 0	-3.0
6536	1-17	968 6	1.6
6537	1-25	969 9	2.9
6538	2-4	967 6	0.6
6539	2-6	967 4	0.4
6540	2-11	967 6	0.6
6541	2-16	968 1	1.1
6542	2-20	966 2	-0.8
MAD			1.4

Charge ID for Temperature Measurement	Sampled Increments Temp ©
1-25C	39.3
1-25E	39.2
2-6A	44.1
2-6C	43.2
2-6E	42.9
2-16C	38.6

Control Group

6523			-2.1
6524			2.5
6525			-0.2
6526			1.9
6527			-0.2
6528			-0.8
6529			1.5
6530			1.1
6531			-1.6
6532			-1.5
MAD			1.3



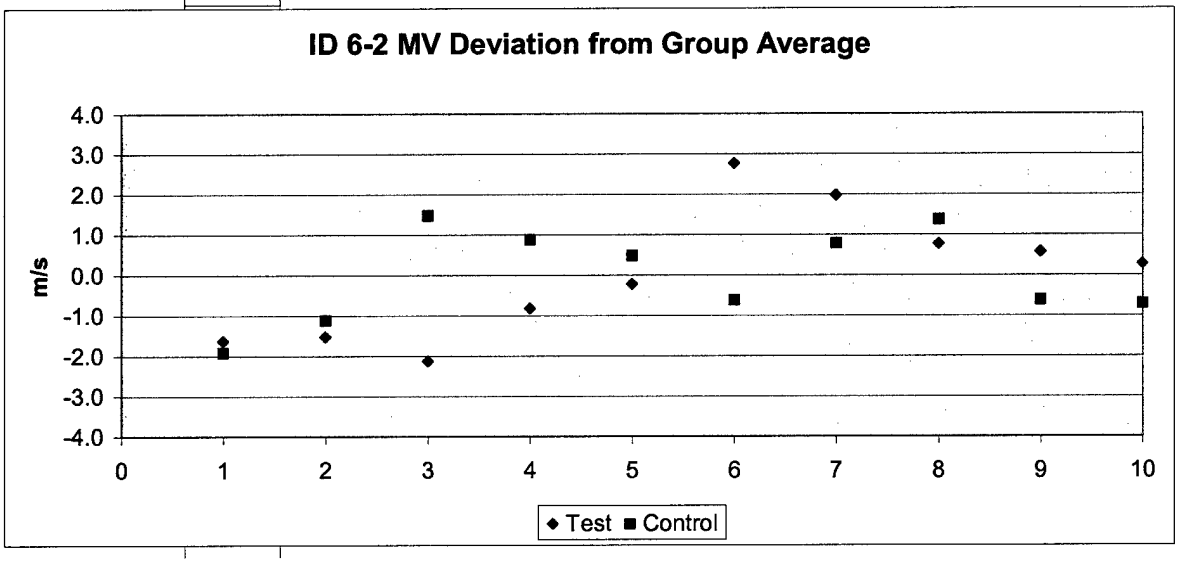
Zone 6 - Occasion 2

SPH Round #	Can #		Ind Vel - Avg Vel of Group
Test Group		**Note: For Zone 6, charges were taken from two pallets, therefore in the cans are identified as 1-2 for Pallet 1 Can 2 and 2-6 for Pallet 2 Can 6**	
6433	1-2	963.1	-1.6
6434	1-7	963.2	-1.5
6435	1-11	962.6	-2.1
6436	1-16	963.9	-0.8
6437	1-20	964.5	-0.2
6438	1-22	967.5	2.8
6439	2-6	966.7	2.0
6440	2-11	965.5	0.8
6441	2-14	965.3	0.6
6442	2-18	965.0	0.3
MAD			1.3

Charge ID for Temperature Measurement	Sampled Increments Temp ©
1-16C	31.4
2-6A	36.4
2-6C	35.9
2-6E	35.2

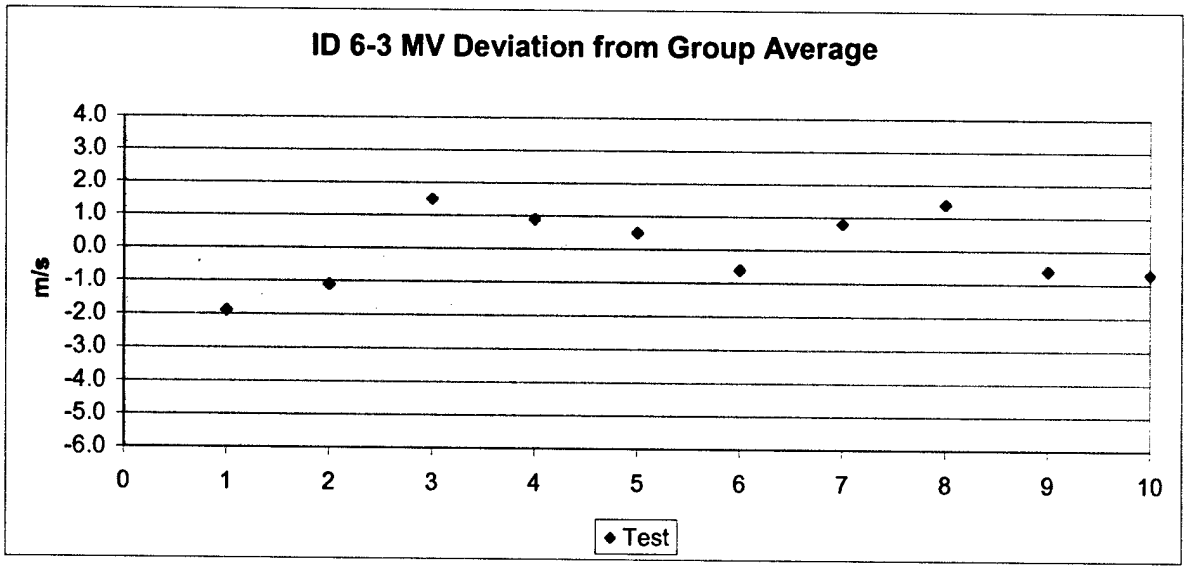
Control Group

6423		966.6	-1.9
6424		963.9	-1.1
6425		964.4	1.5
6426		963.7	0.9
6427		965.8	0.5
6428		965.1	-0.6
6429		965.0	0.8
6430		964.4	1.4
6431		964.2	-0.6
6432		965.5	-0.7
MAD			1.0



Zone 6 - Occasion 3

SPH Round #	Can #		Ind Vel - Avg Vel of Group		Charge ID for Temperature Measurement	Sampled Increments Temp C
Test Group						
		No Control group data due to long break between rounds in the group				
6393	1-3	966 6	1.7		1-16C	31
6394	1-7	963 9	-1.0			
6395	1-9	964 4	-0.5			
6396	1-12	963 7	-1.2			
6397	1-13	965 8	0.9			
6398	1-16	965 1	0.2			
6399	1-19	965 0	0.1			
6400	1-23	964 4	-0.5			
6401	1-26	964 2	-0.7			
6402	1-29	965 5	0.6			
MAD			0.7			



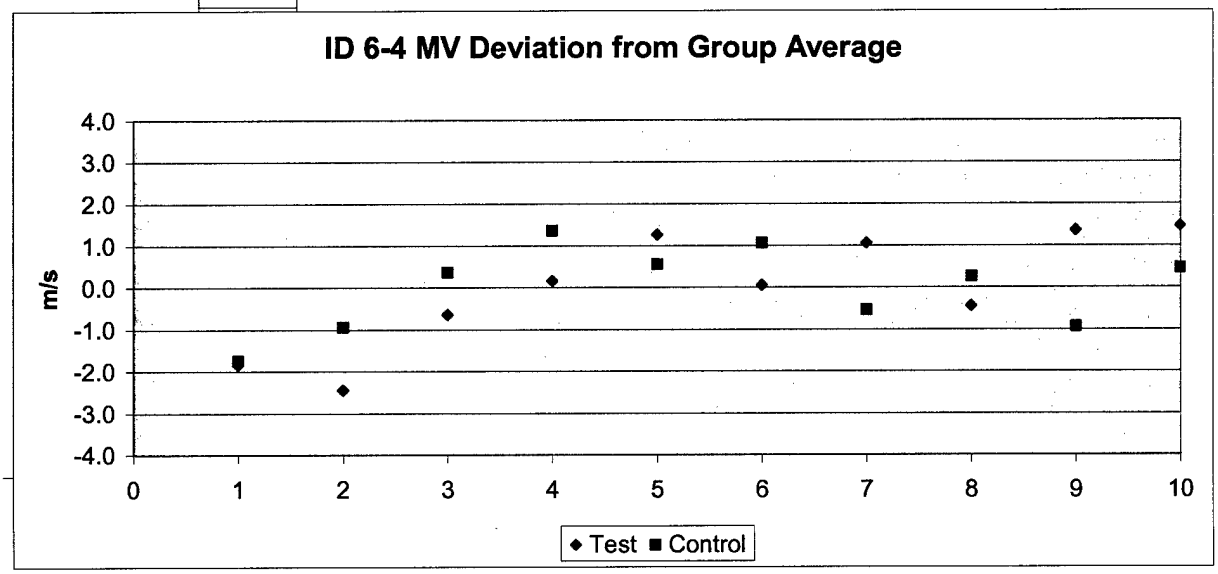
Zone 6 - Occasion 4

SPH Round #	Can #		Ind Vel - Avg Vel of Group
Test Group		Note: For Zone 6, charges were taken from two pallets, therefore in the cans are identified as 1-4 for Pallet 1 Can 4 and 2-8 for Pallet 2 Can 8	
6244	1-4	954.6	-1.8
6245	1-25	954.0	-2.4
6246	2-1	955.8	-0.6
6247	2-4	956.6	0.2
6248	2-8	957.7	1.3
6249	2-13	956.5	0.1
6250	2-16	957.5	1.1
6251	2-19	956.0	-0.4
6252	2-23	957.8	1.4
6253	2-26	957.9	1.5
	2-28		
MAD			1.1

Charge ID for Temperature Measurement	Sampled Increments Temp ©
1-25A	20.9
1-25C	21.4
1-25E	21.3
2-1A	21.6
2-1C	21.6
2-1E	21.2
2-16C	23.0

Control Group

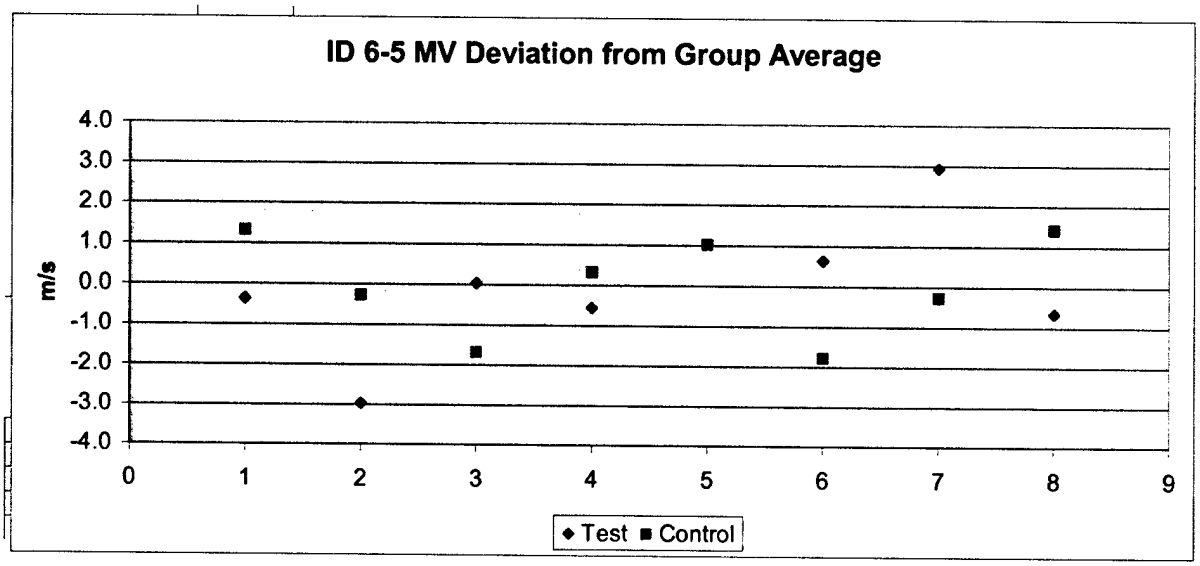
6254			-1.7
6255			-0.9
6256			0.4
6257			1.4
6258			0.6
6259			1.1
6260			-0.5
6261			0.3
6262			-0.9
6263			0.5
MAD			0.8



Zone 6 - Occasion 5

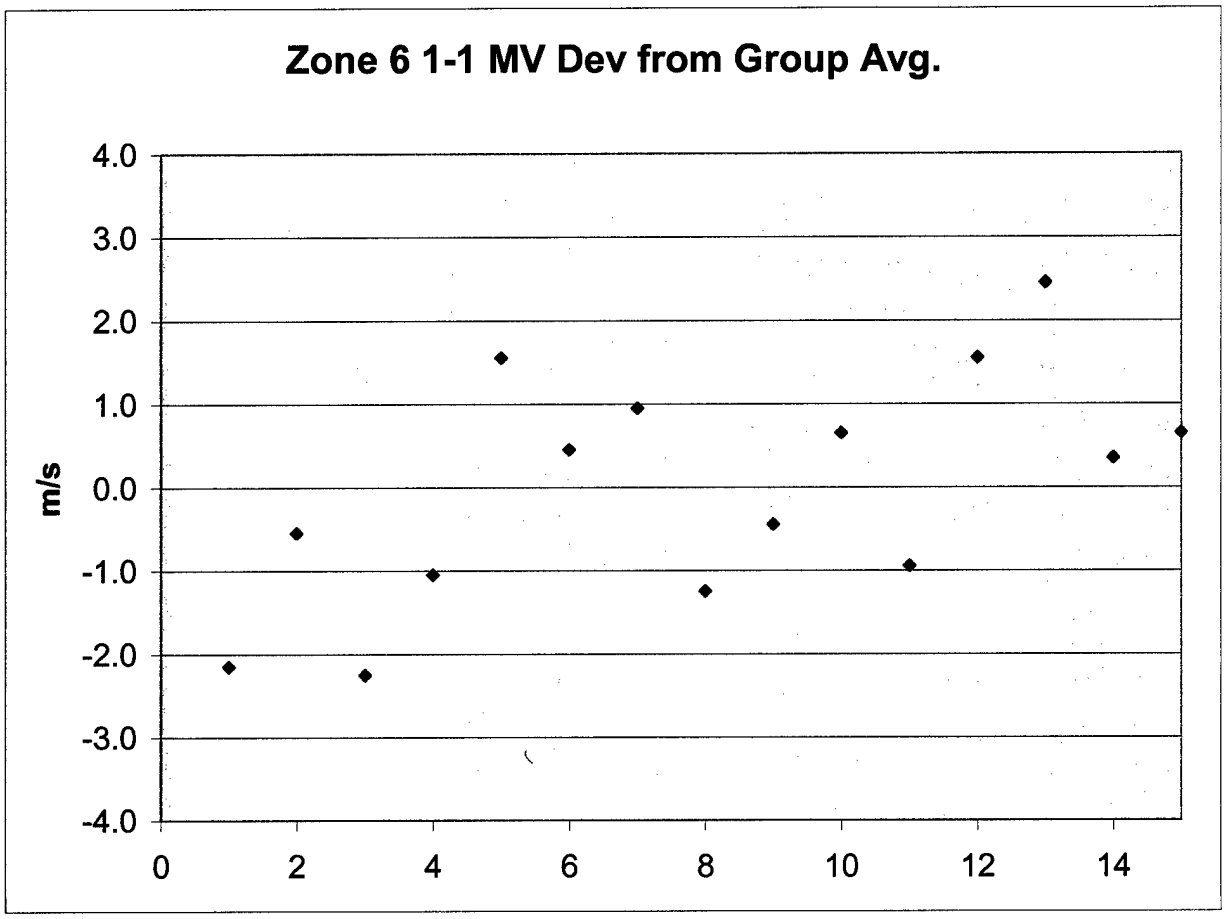
SPH Round #	Can #		Ind Vel - Avg Vel of Group
Test Group			
6355	1-3	960 7	-0.4
6356	1-5	958 1	-3.0
6357	1-9	961 1	0.0
6358	1-12	960 5	-0.6
6359	1-15	962 1	1.0
6360	1-17	961 7	0.6
6361	1-21	964 0	2.9
6362	1-24	960 4	-0.7
	1-27		
	1-30		
MAD			1.2
Control Group			
6347			1.3
6348			-0.3
6349			-1.7
6350			0.3
6351			1.0
6352			-1.8
6353			-0.3
6354			1.4
MAD			0.8

Charge ID for Temperature Measurement	Sampled Increments Temp ©
1-27C	23.2
1-30A	28.9
1-30C	27.7
1-30E	28.8

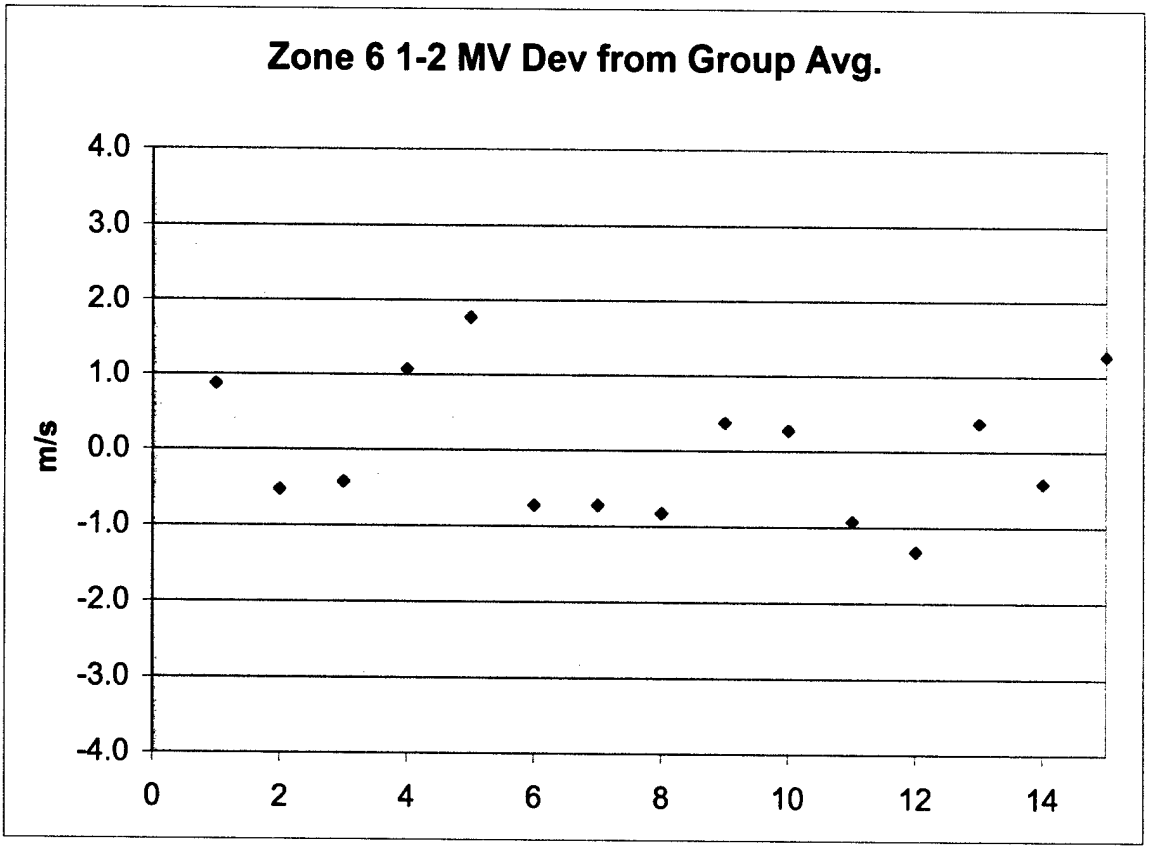


Phase 2

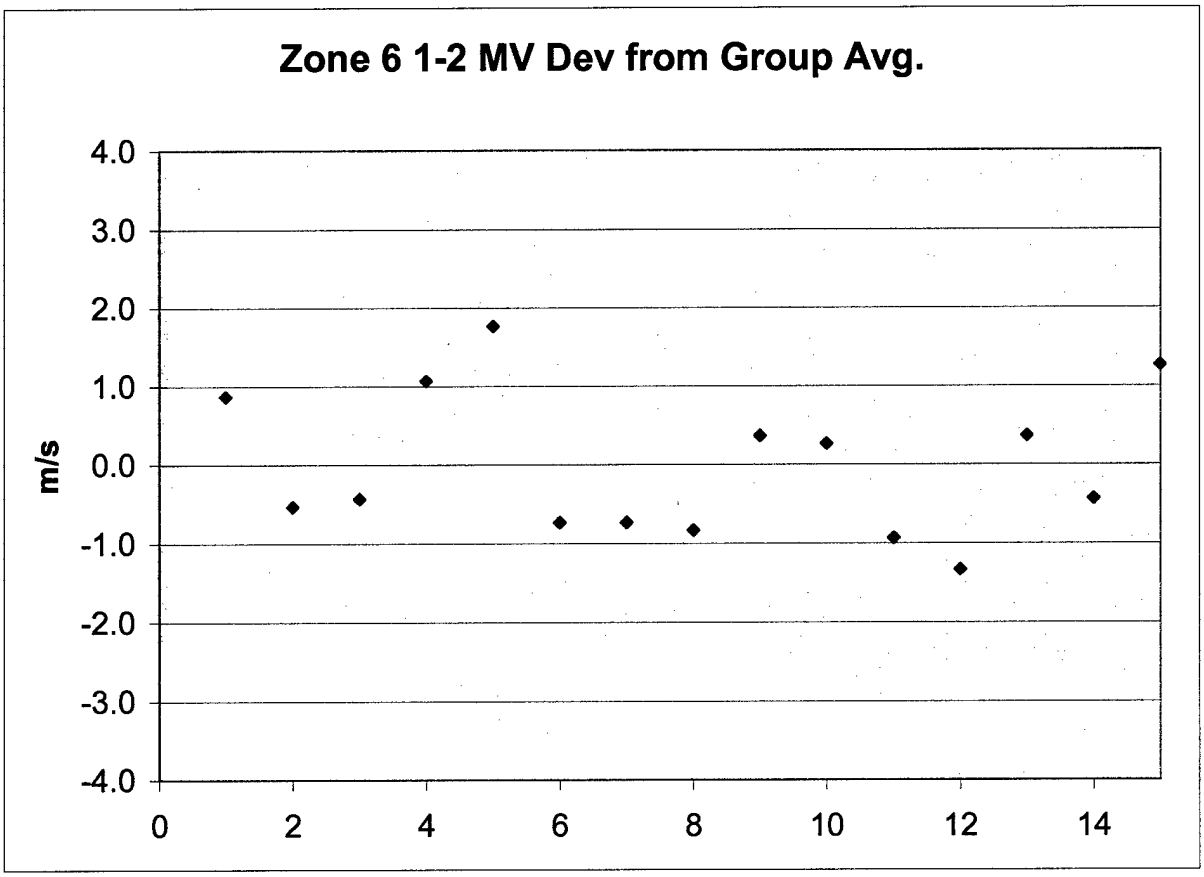
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
1-1	30.9	-2.1
	30.7	-0.5
	31.7	-2.2
	31.9	-1.0
	32.6	1.6
	32.5	0.5
	33.4	1.0
	32.9	-1.2
	32.6	-0.4
	32.3	0.7
		-0.9
		1.6
		2.5
		0.4
		0.7



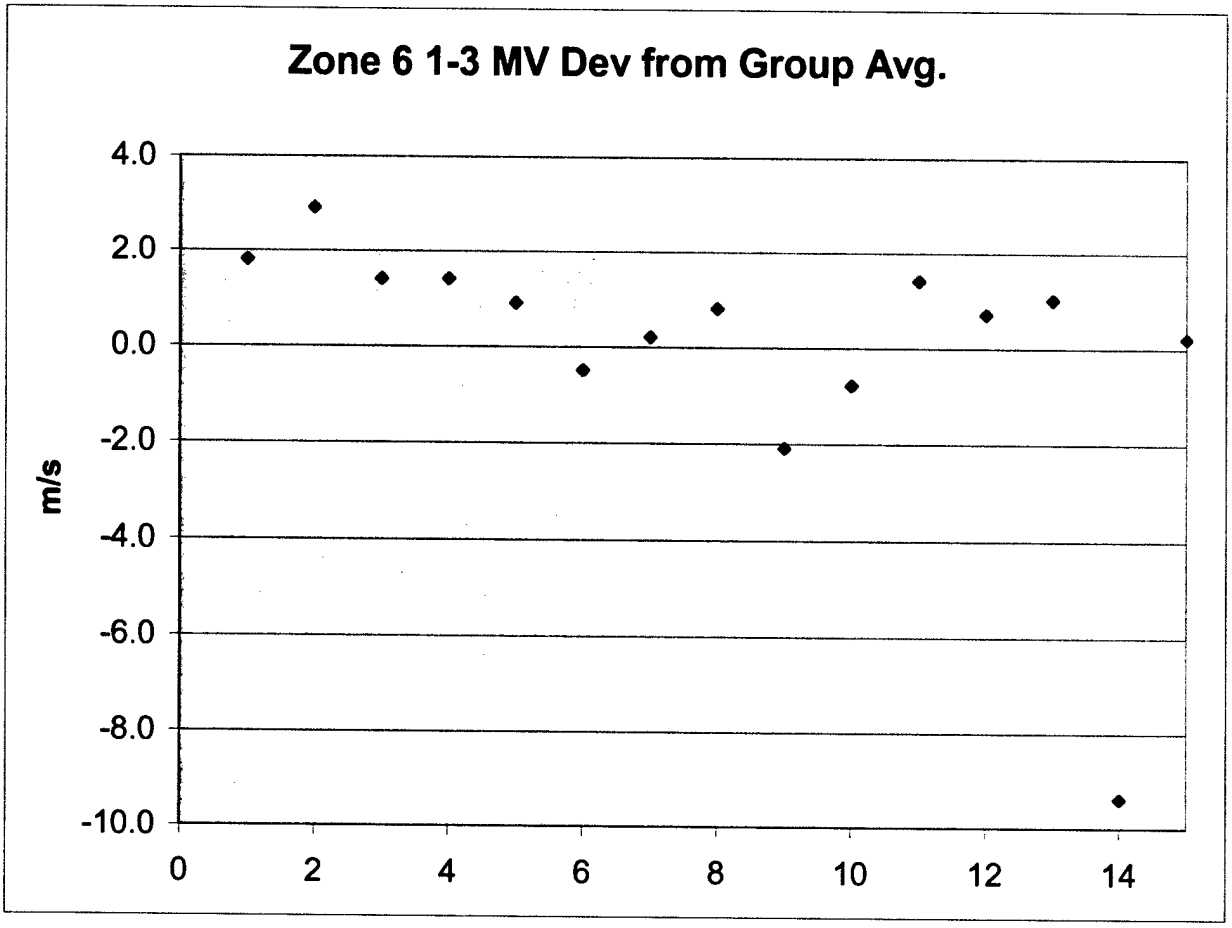
Zone 6 Mission ID	Sampled Increments Temp C	Velocity Measured - Average Velocity of Group
1-2	34.3	0.9
	33.3	-0.5
	35.2	-0.4
	34.9	1.1
	34.4	1.8
	33.9	-0.7
	33.7	-0.7
	33.9	-0.8
	34.4	0.4
	33.9	0.3
		-0.9
		-1.3
		0.4
		-0.4
		1.3



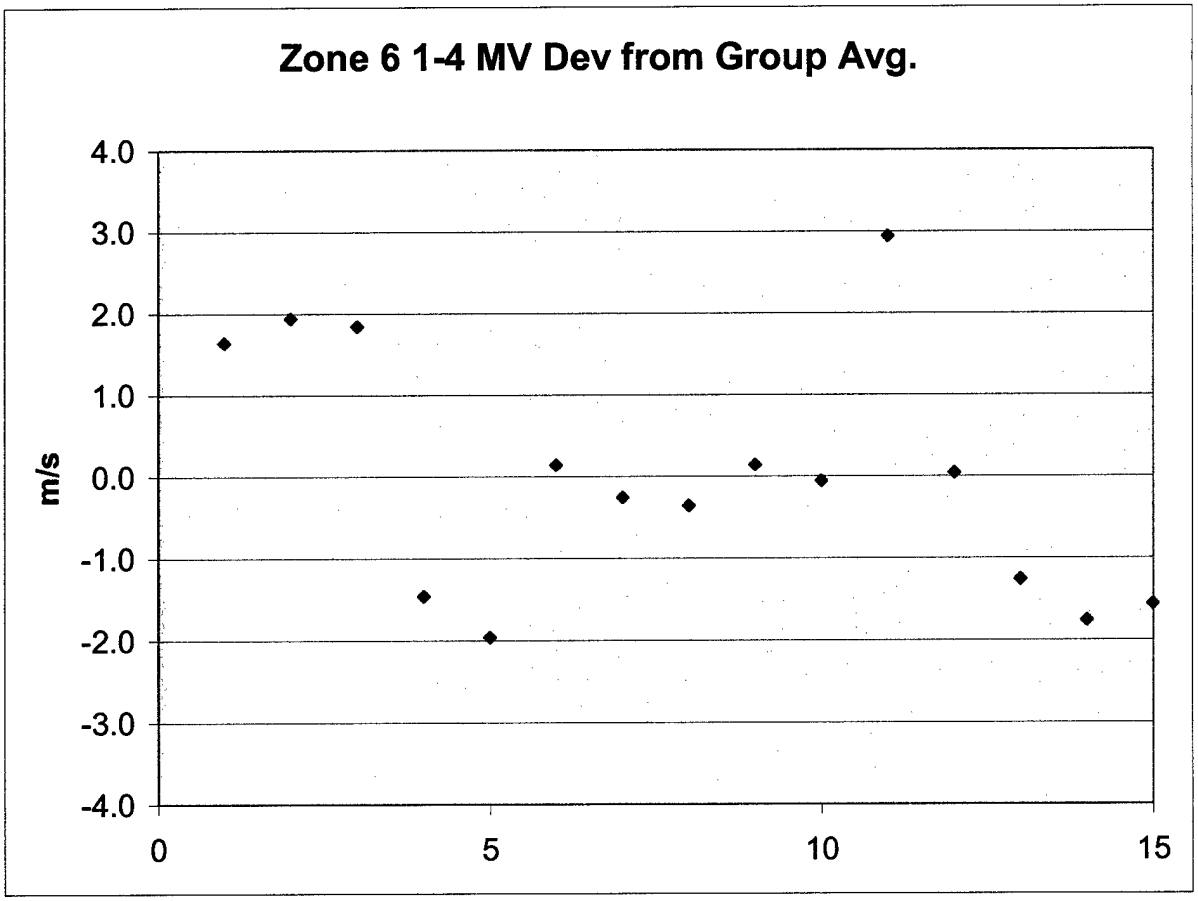
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
1-2	34.3	0.9
	33.3	-0.5
	35.2	-0.4
	34.9	1.1
	34.4	1.8
	33.9	-0.7
	33.7	-0.7
	33.9	-0.8
	34.4	0.4
	33.9	0.3
		-0.9
		-1.3
		0.4
		-0.4
		1.3



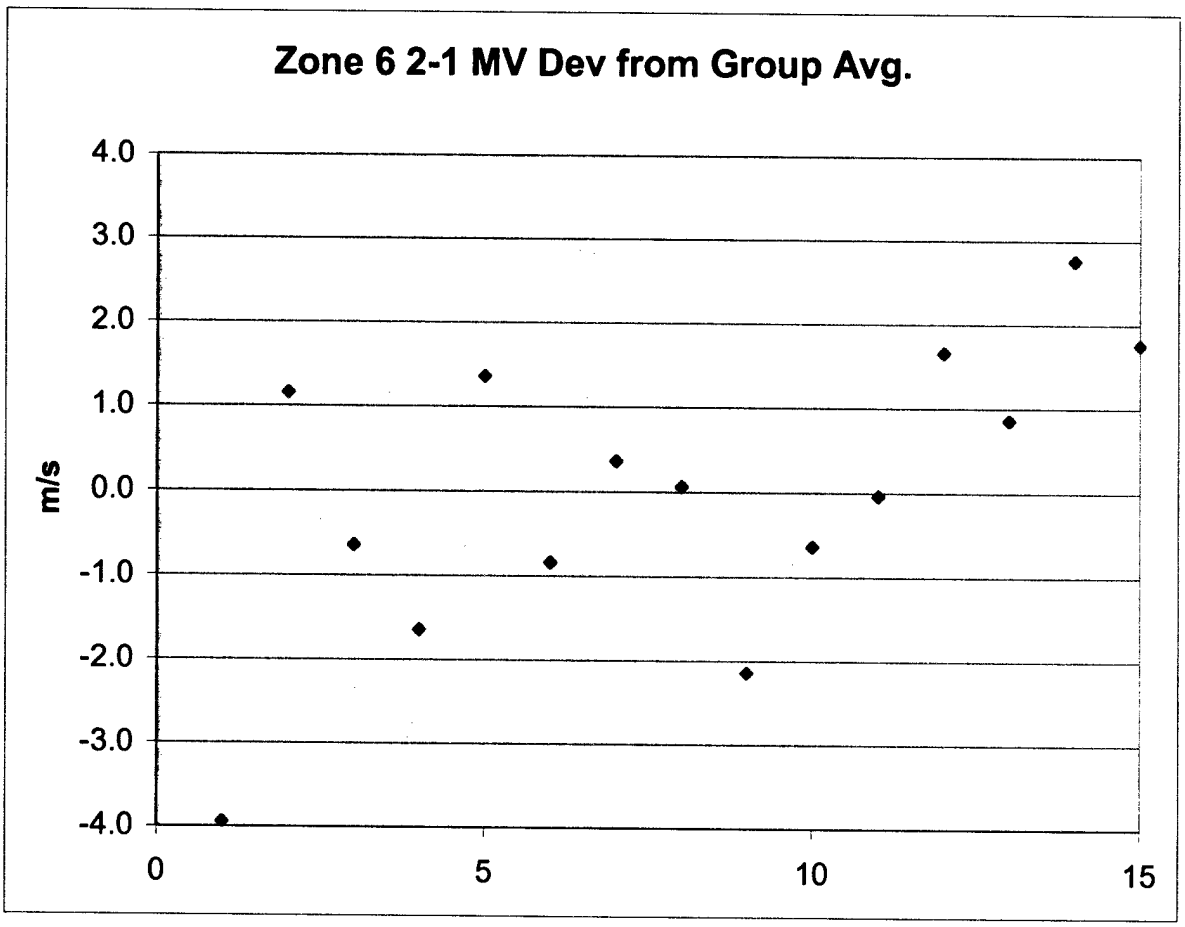
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
1-3	40.8	1.8
	41.0	2.9
	41.4	1.4
	40.3	1.4
	38.3	0.9
	39.1	-0.5
	39.4	0.2
	39.2	0.8
	40.9	-2.1
	40.4	-0.8
		1.4
		0.7
		1.0
		-9.4
		0.2



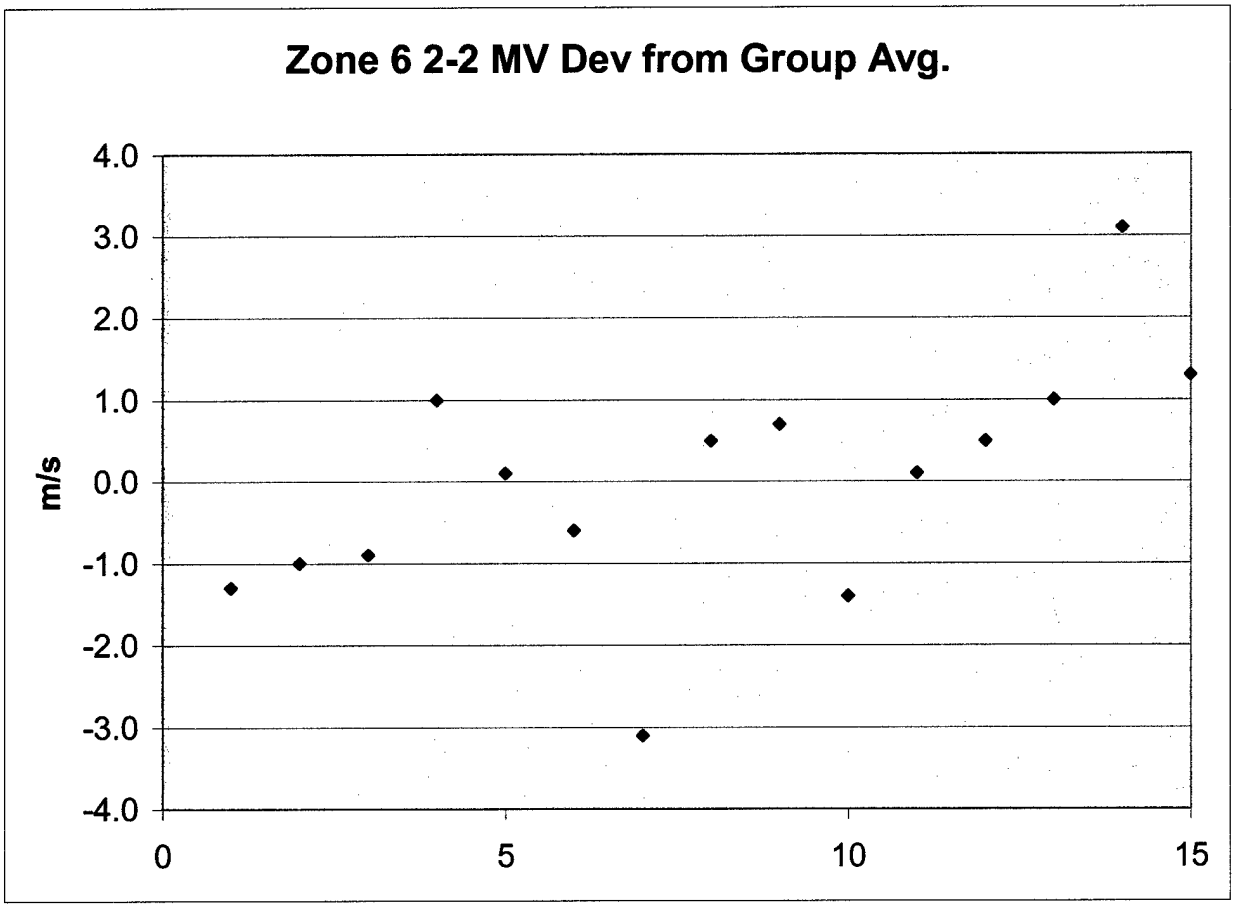
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
1-4	45.0	1.6
	43.4	1.9
	45.0	1.8
	44.5	-1.5
	39.5	-2.0
	40.2	0.1
	39.6	-0.3
	42.3	-0.4
	41.7	0.1
	42.1	-0.1
		2.9
		0.0
		-1.3
		-1.8
		-1.6



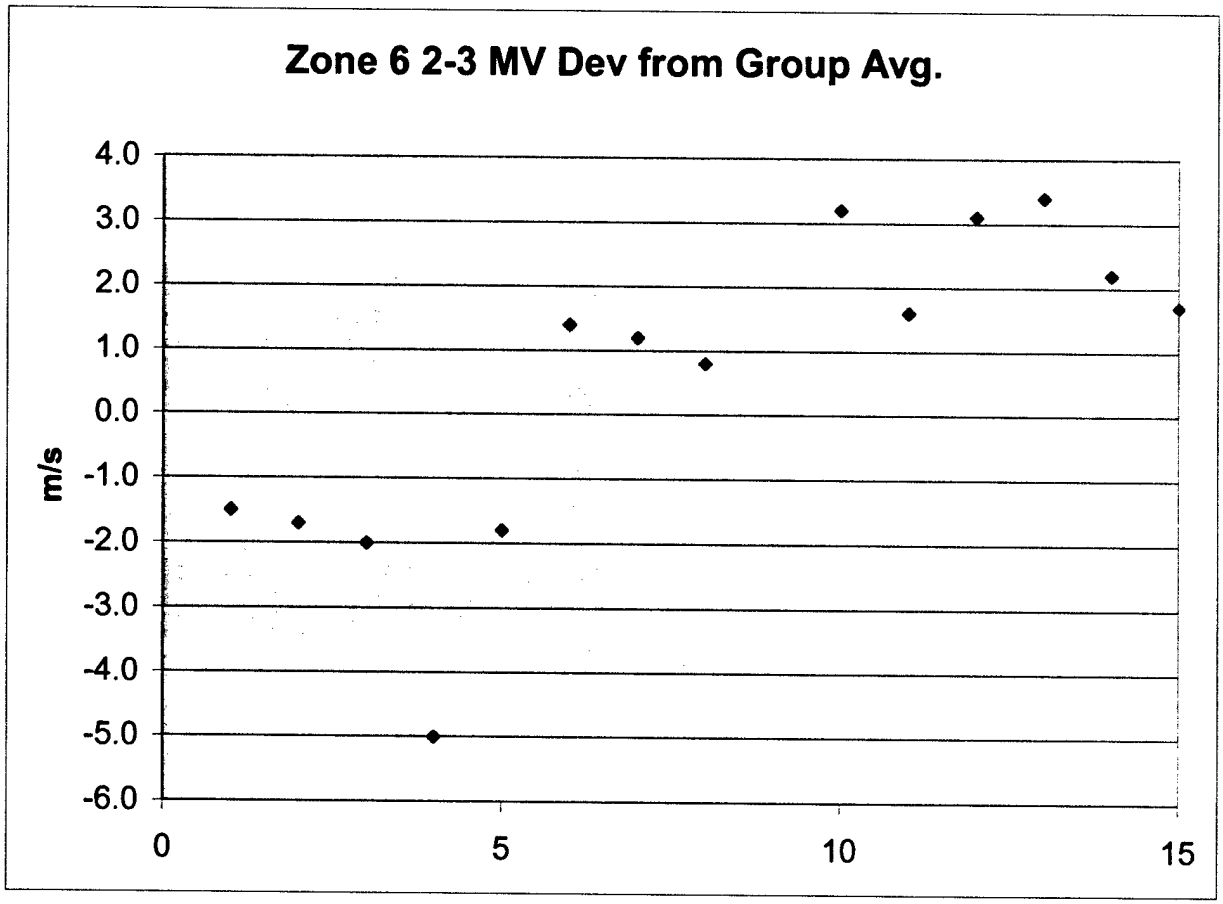
Zone 6 Mission ID	Sampled Increments Temp Θ	Velocity Measured - Average Velocity of Group
2-1	29.7	-3.9
	29.7	1.2
	29.9	-0.6
	29.6	-1.6
	30.6	1.4
	30.4	-0.8
	30.8	0.4
	30.1	0.1
	30.8	-2.1
	30.4	-0.6
		0.0
		1.7
		0.9
		2.8
		1.8



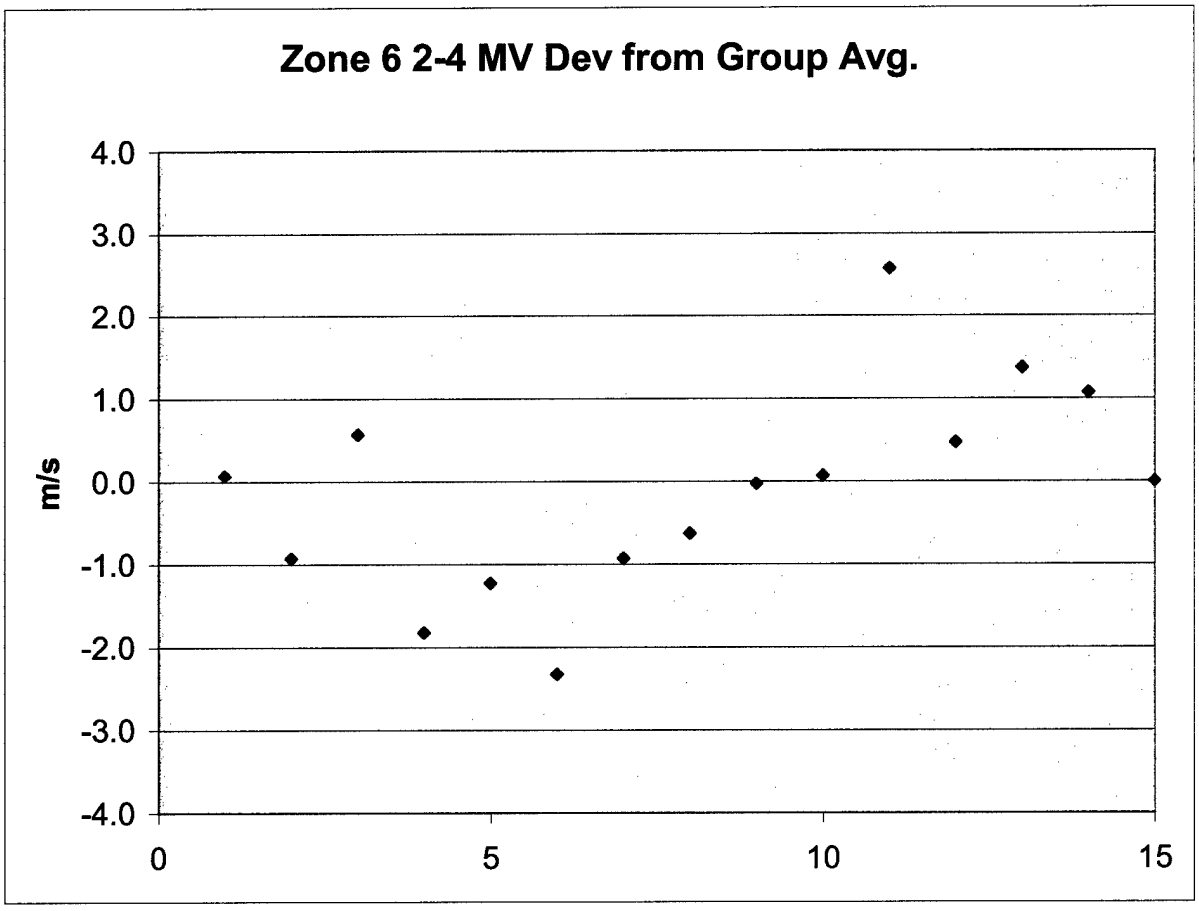
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
2-2	30.3	-1.3
	29.7	-1.0
	30.8	-0.9
	29.8	1.0
	30.0	0.1
	29.8	-0.6
	30.3	-3.1
	30.0	0.5
	30.3	0.7
	29.7	-1.4
		0.1
		0.5
		1.0
		3.1
		1.3



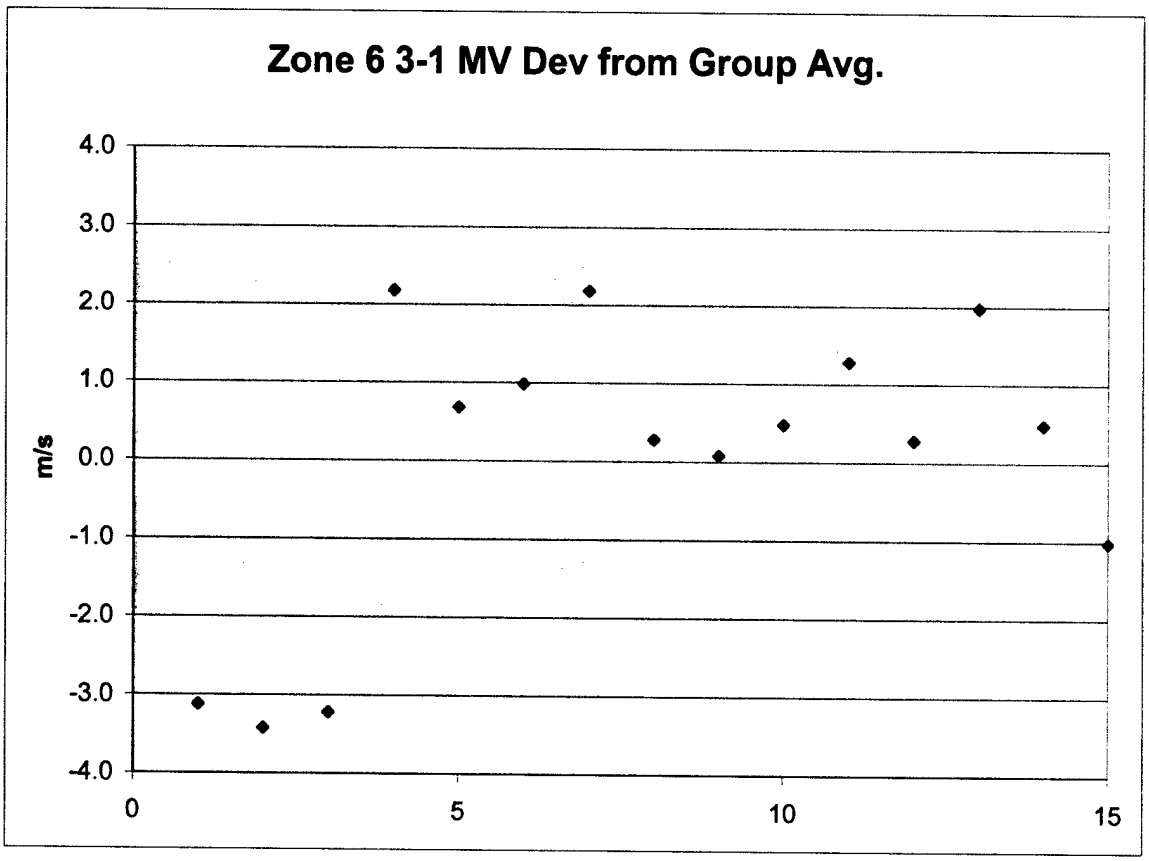
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
2-3	32.8	-1.5
	32.1	-1.7
	33.2	-2.0
	31.9	-5.0
	30.6	-1.8
	30.9	1.4
	30.8	1.2
	32.1	0.8
	31.9	-6.5
	31.7	3.2
		1.6
		3.1
		3.4
		2.2
		1.7



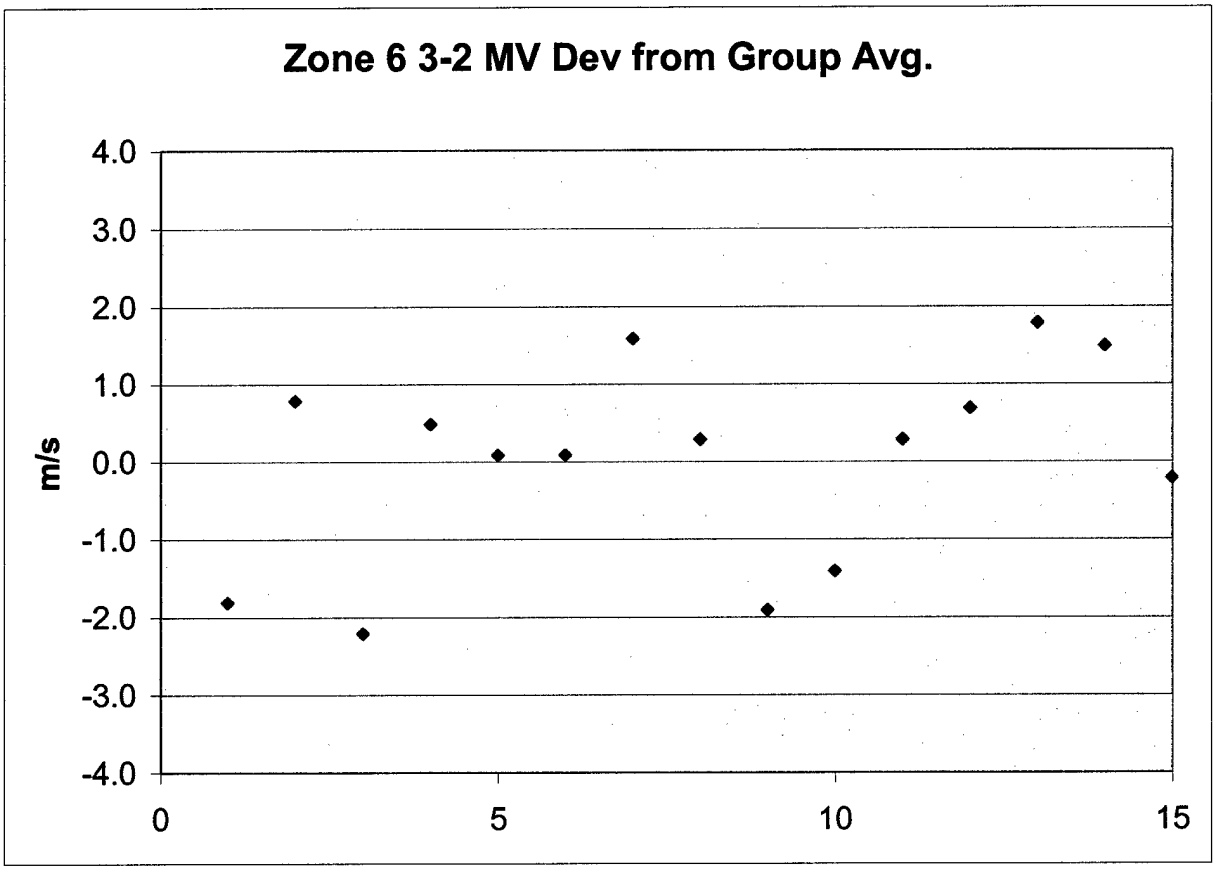
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
2-4	35.3	0.1
	33.7	-0.9
	36.6	0.6
	35.9	-1.8
	31.8	-1.2
	31.7	-2.3
	32.6	-0.9
	33.2	-0.6
	35.0	0.0
	33.3	0.1
		2.6
		0.5
		1.4
		1.1
		#REF!



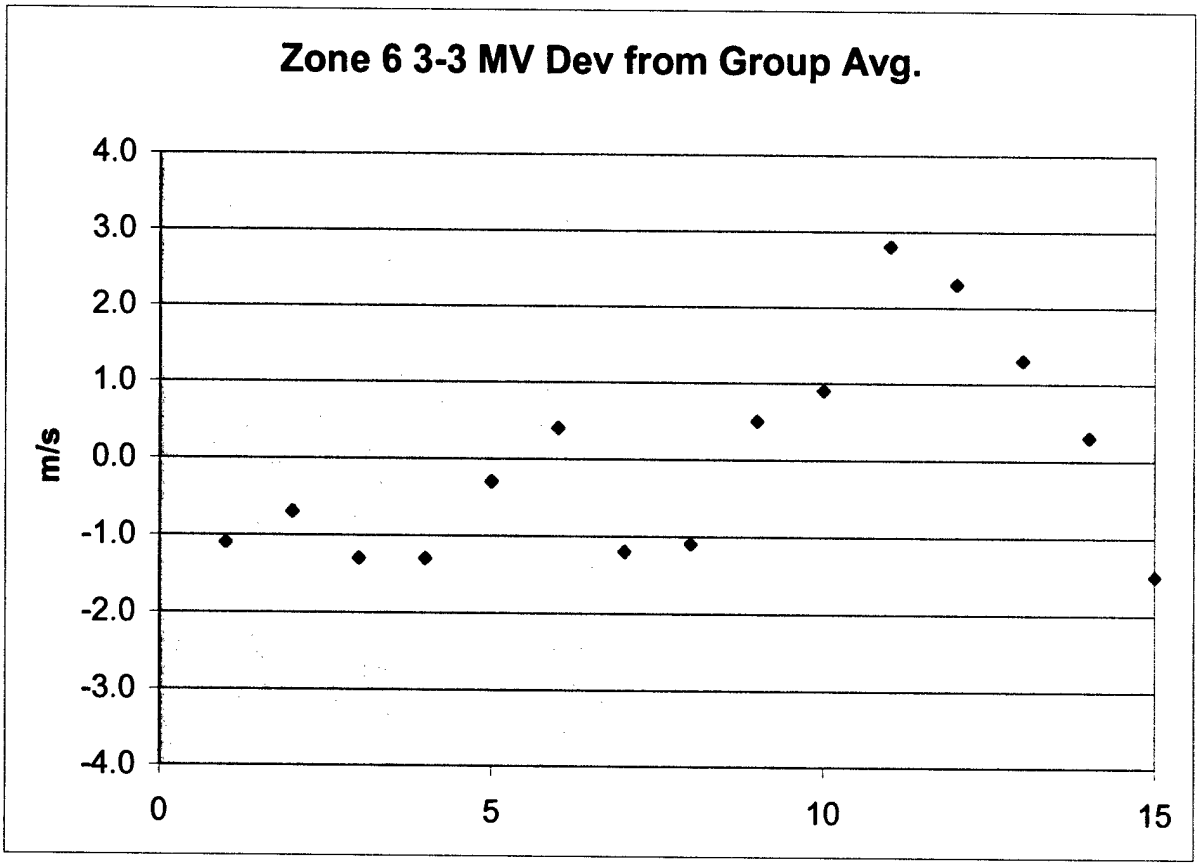
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
3-1	27.5	-3.1
	27.3	-3.4
	27.9	-3.2
	27.7	2.2
	27.8	0.7
	27.5	1.0
	27.6	2.2
	27.4	0.3
	28.4	0.1
	28.4	0.5
		1.3
		0.3
		2.0
		0.5
		-1.0



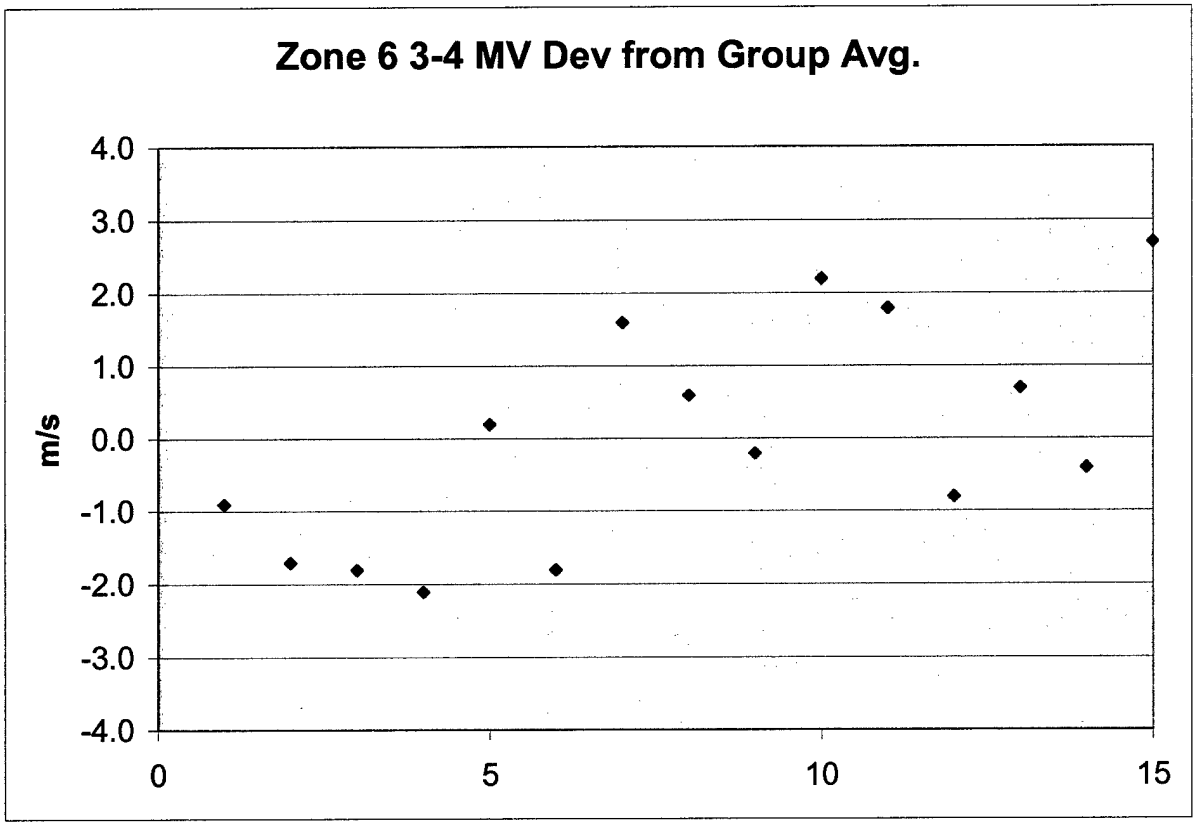
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
3-2	29.6	-1.8
	29.2	0.8
	30.5	-2.2
	30.4	0.5
	28.7	0.1
	29.6	0.1
	29.4	1.6
	29.0	0.3
	30.2	-1.9
	29.1	-1.4
		0.3
		0.7
		1.8
		1.5
		-0.2



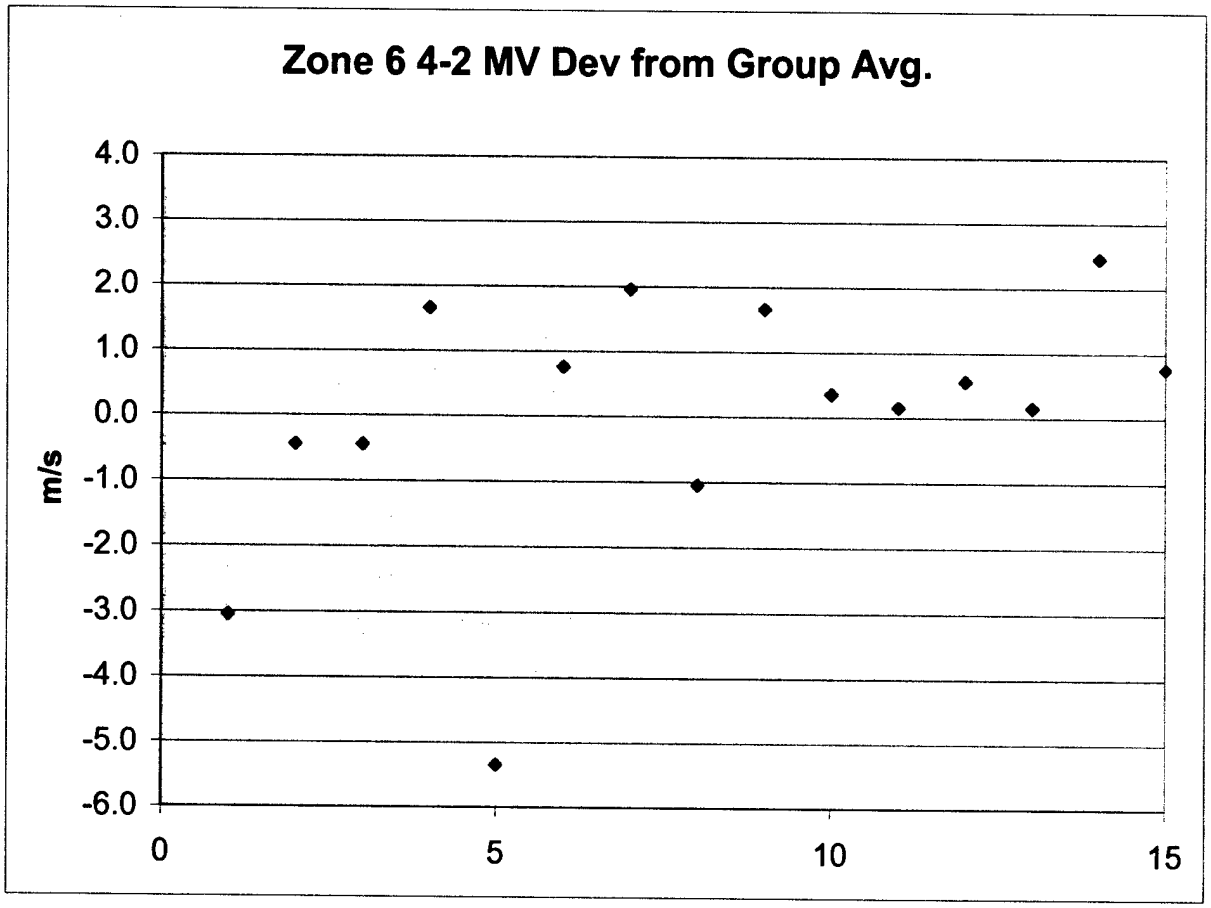
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
3-3	31.8	-1.1
	30.8	-0.7
	32.6	-1.3
	30.7	-1.3
	29.8	-0.3
	30.2	0.4
	29.7	-1.2
	29.4	-1.1
	29.6	0.5
	29.7	0.9
		2.8
		2.3
		1.3
		0.3
		-1.5



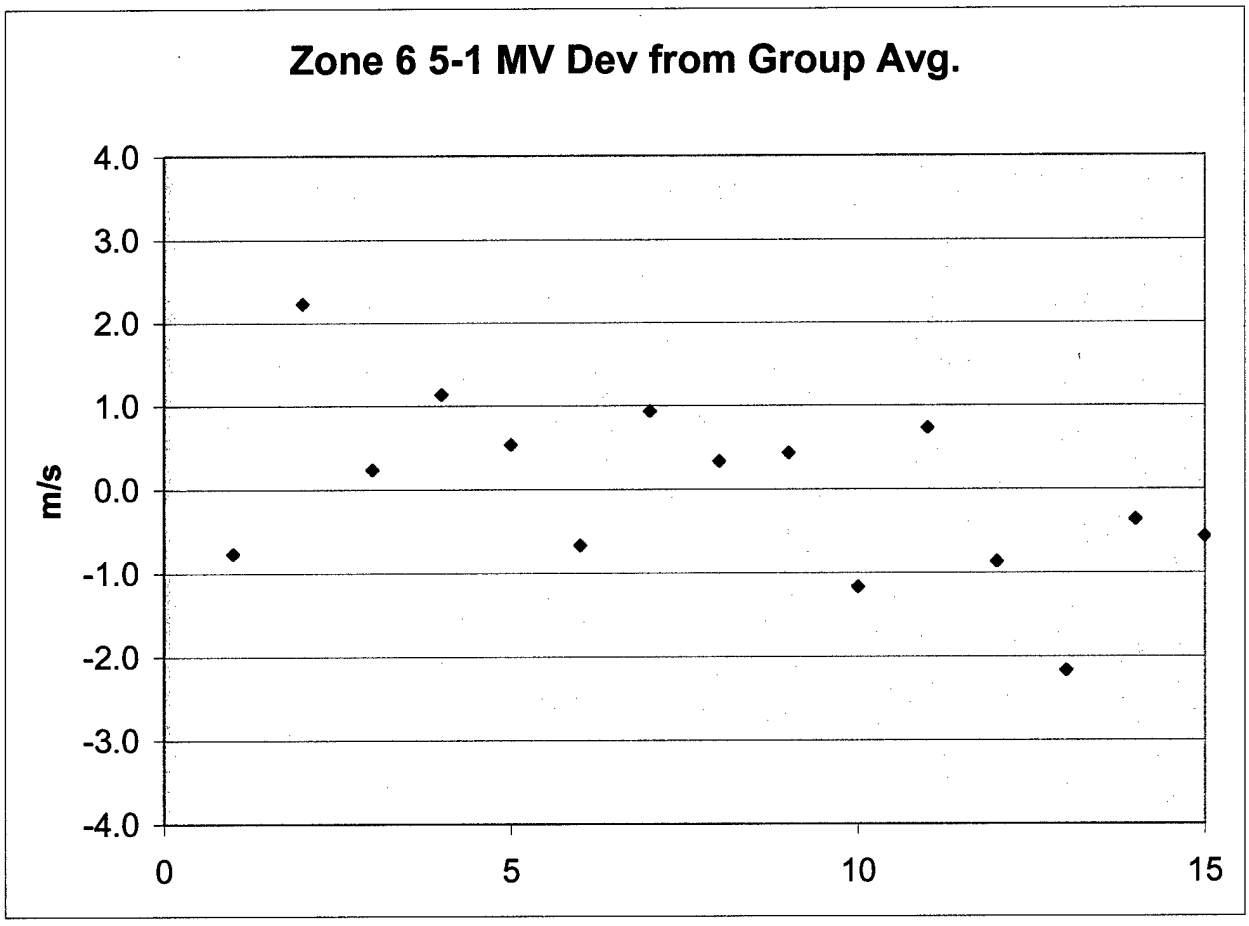
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
3-4	32.9	-0.9
	31.9	-1.7
	33.8	-1.8
	33.8	-2.1
	30.3	0.2
	30.3	-1.8
	30.3	1.6
	31.5	0.6
	32.8	-0.2
	34.4	2.2
		1.8
		-0.8
		0.7
		-0.4
		2.7



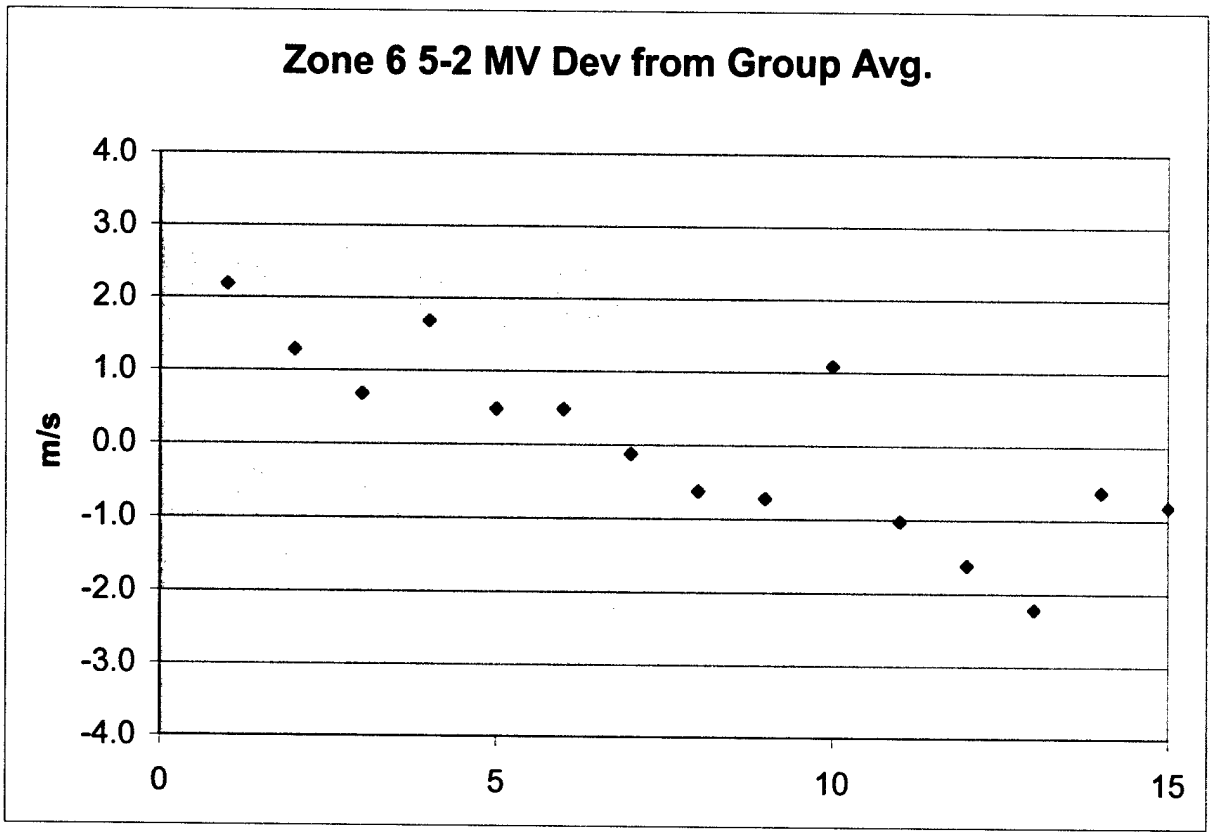
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
4-2	35.1	-3.1
	34.5	-0.5
	35.5	-0.5
	34.1	1.6
	32.7	-5.4
	32.7	0.7
	32.7	1.9
	32.6	-1.1
	33.9	1.6
	32.7	0.3
		0.1
		0.5
		0.1
		2.4
		0.7



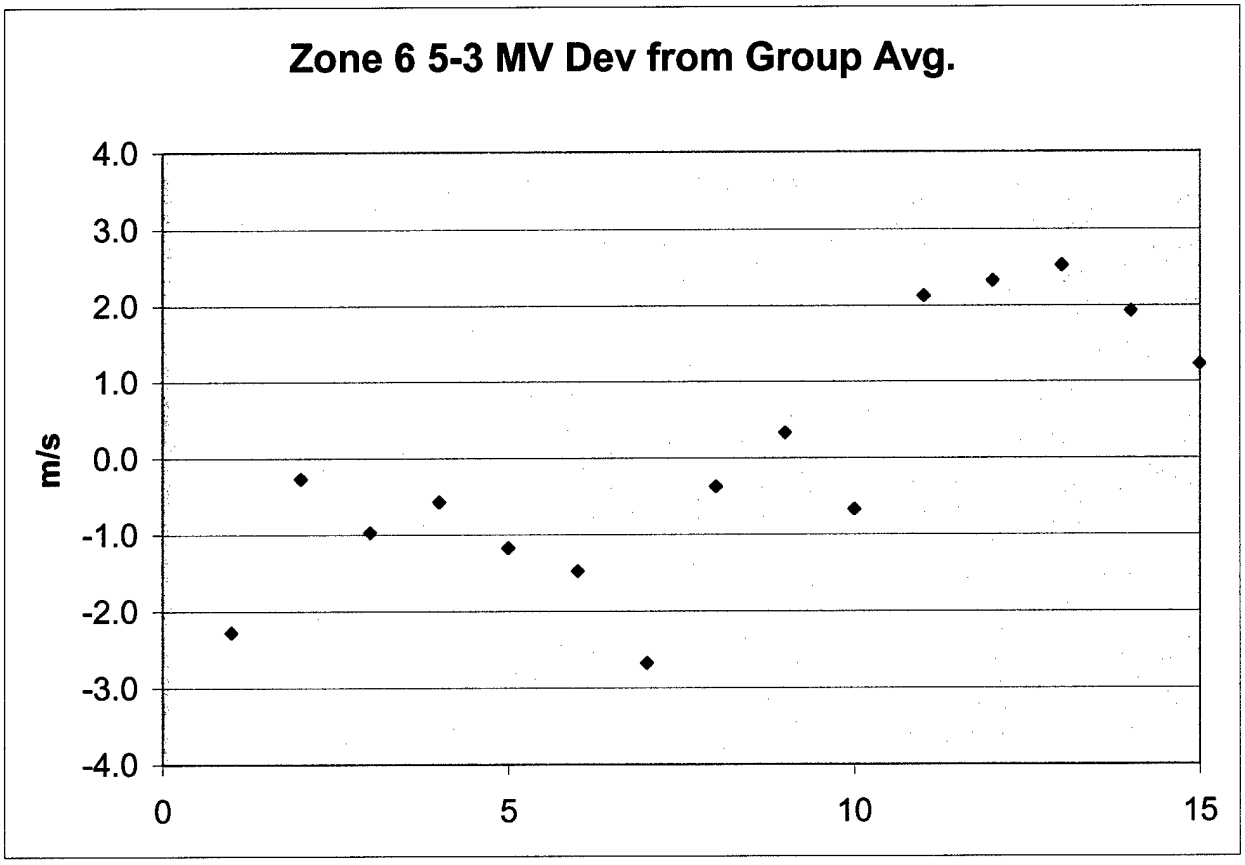
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
5-1	32.3	-0.8
	31.1	2.2
	33.3	0.2
	31.7	1.1
	31.8	0.5
	31.8	-0.7
	32.0	0.9
	31.3	0.3
	33.2	0.4
	31.8	-1.2
		0.7
		-0.9
		-2.2
		-0.4
		-0.6



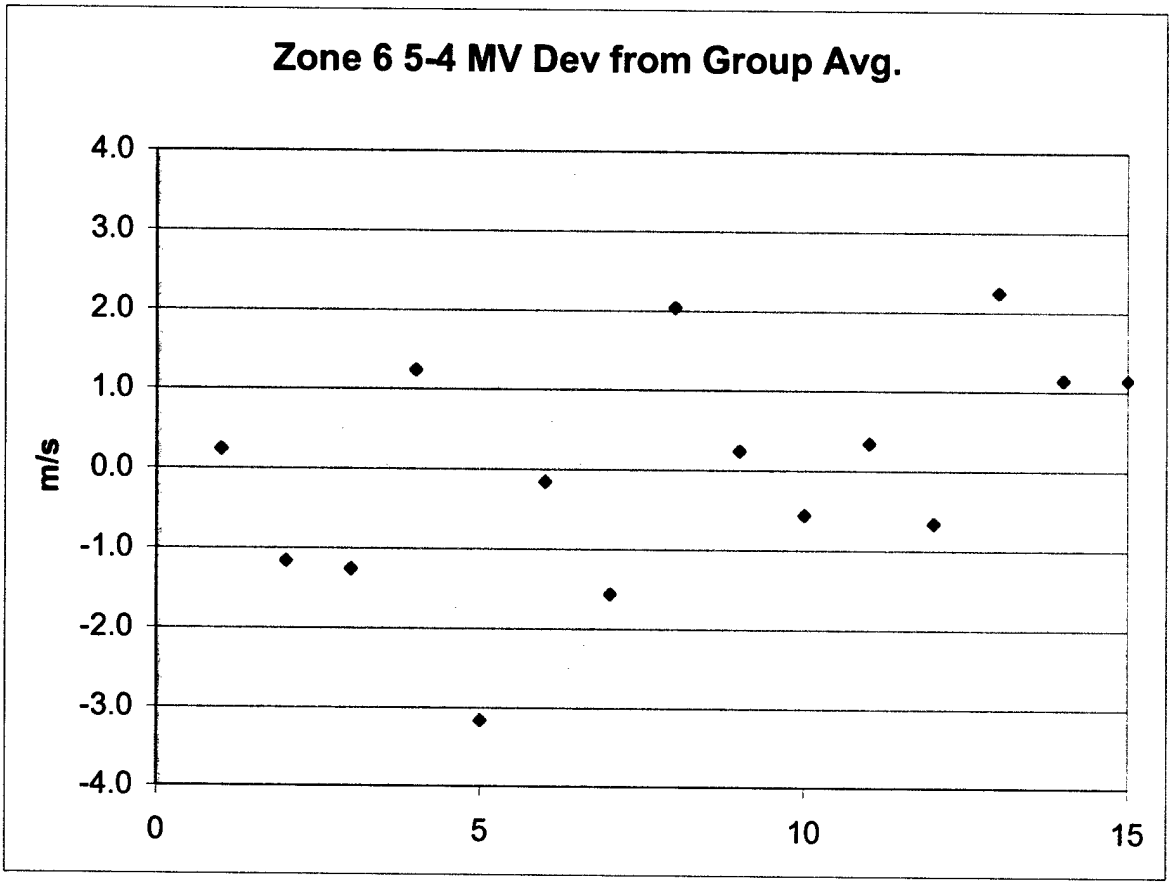
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
5-2	34.9	2.2
	33.2	1.3
	34.8	0.7
	33.7	1.7
	33.6	0.5
	32.6	0.5
	32.2	-0.1
	32.4	-0.6
	33.6	-0.7
	32.8	1.1
		-1.0
		-1.6
		-2.2
		-0.6
		-0.8



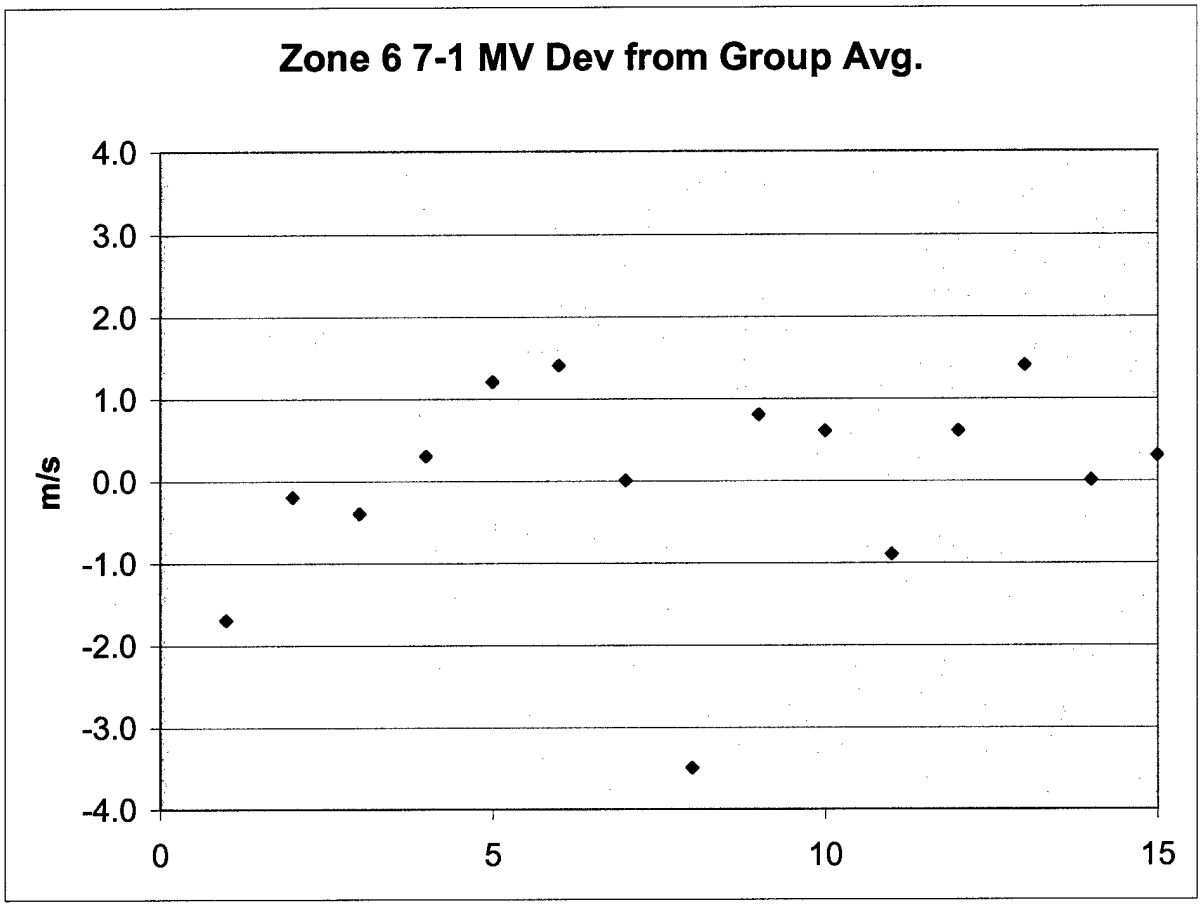
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
5-3	39.9	-2.3
	37.7	-0.3
	40.9	-1.0
	37.9	-0.6
	35.4	-1.2
	35.7	-1.5
	36.4	-2.7
	35.6	-0.4
	37.1	0.3
	36.5	-0.7
		2.1
		2.3
		2.5
		1.9
		1.2



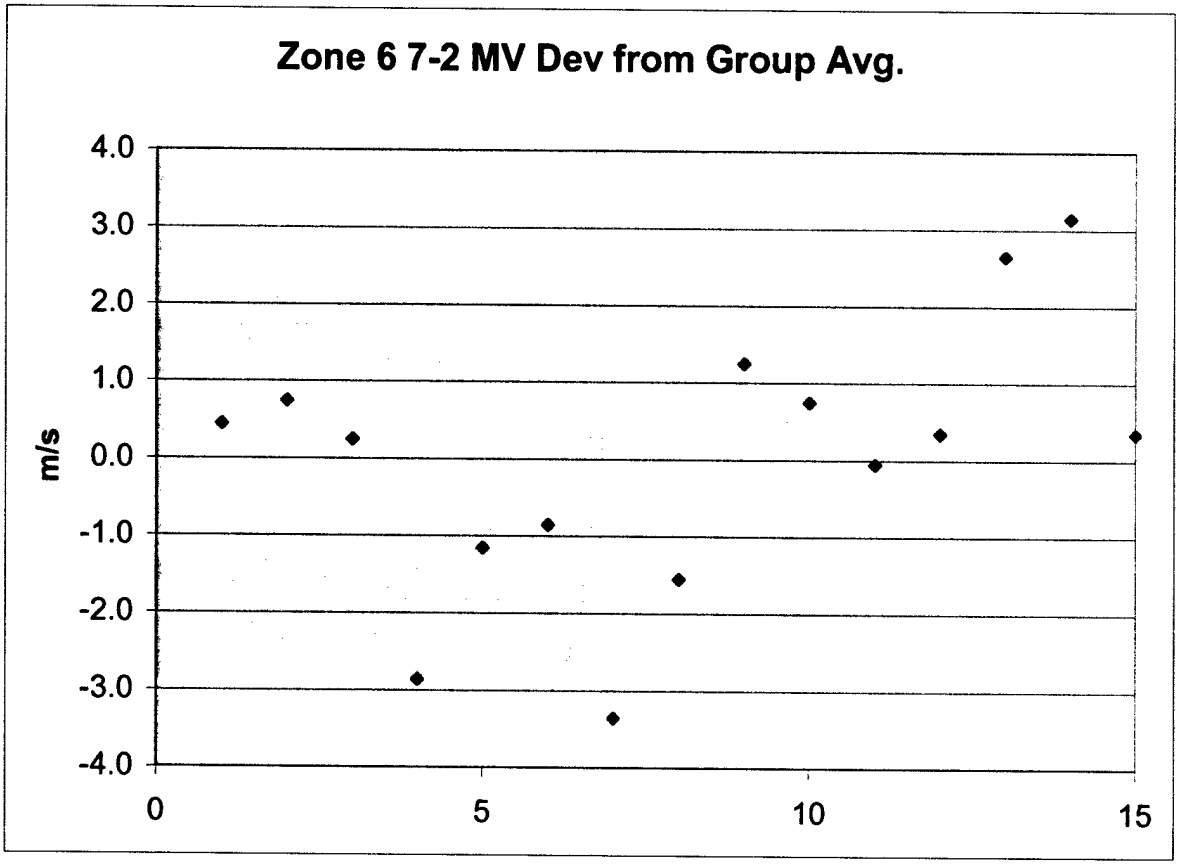
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
5-4	41.8	0.2
	41.3	-1.2
	44.2	-1.3
	43.0	1.2
	37.5	-3.2
	37.1	-0.2
	37.3	-1.6
	40.4	2.0
	40.3	0.2
	38.3	-0.6
		0.3
		-0.7
		2.2
		1.1
		1.1



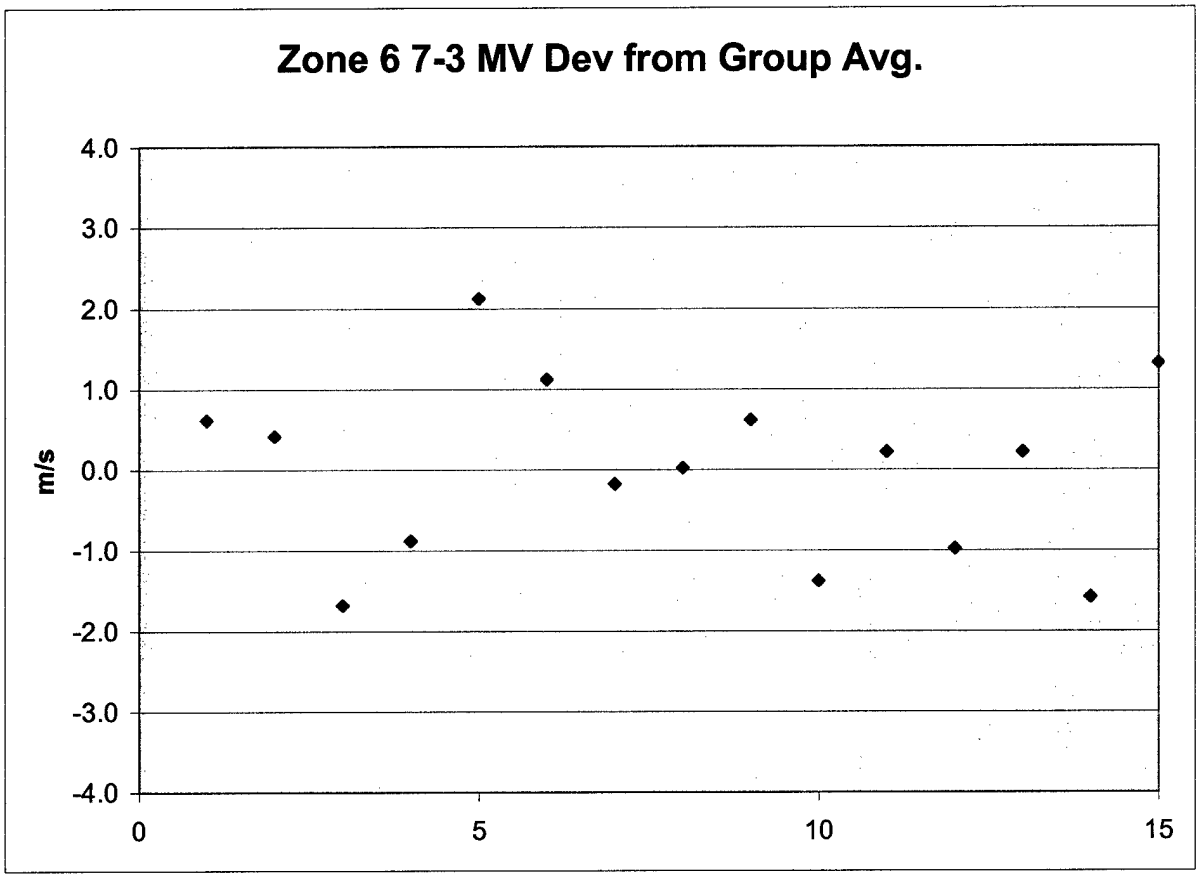
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
7-1	27.2	-1.7
	27.8	-0.2
	27.3	-0.4
	27.3	0.3
	28.3	1.2
	28.7	1.4
	27.9	0.0
	28.0	-3.5
	28.0	0.8
	27.1	0.6
		-0.9
		0.6
		1.4
		0.0
		0.3



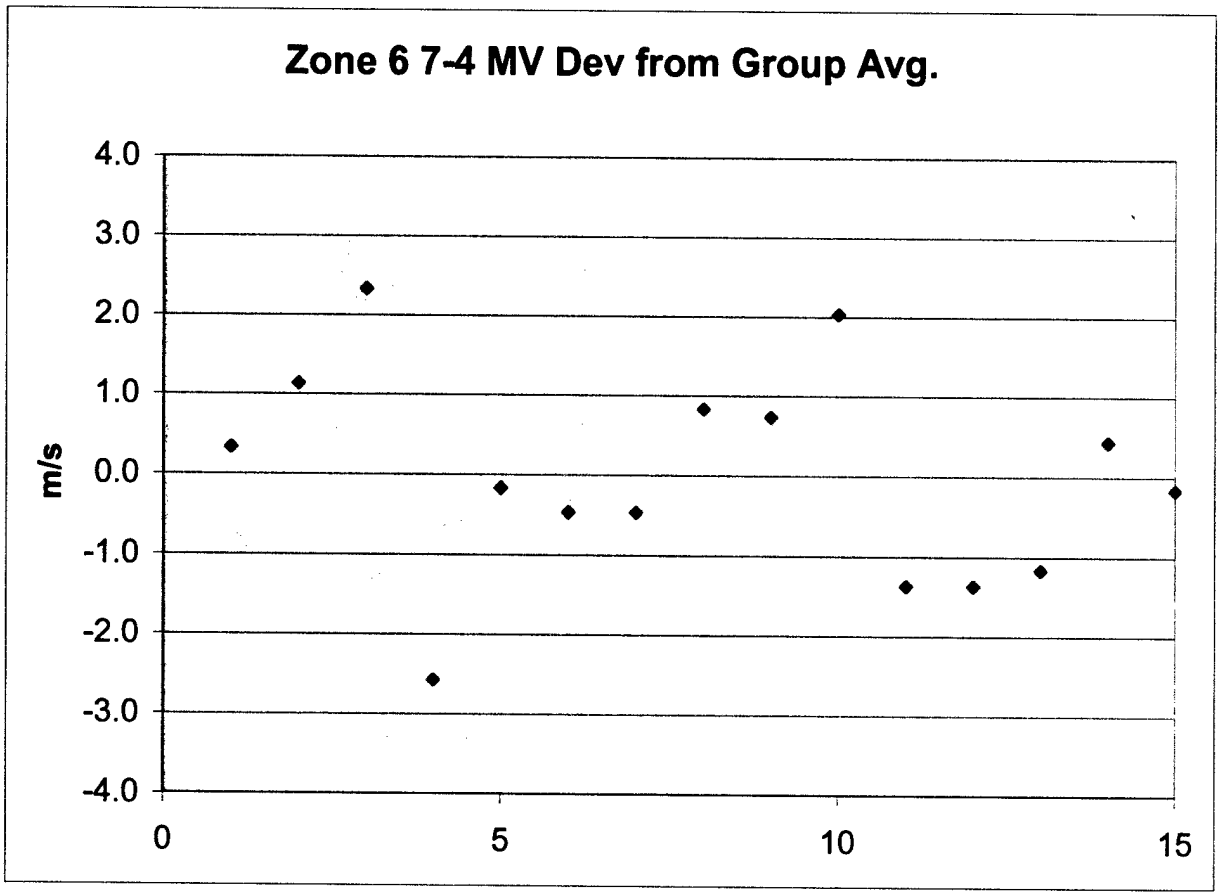
Zone 6 Mission ID	Sampled Increments Temp ⊖	Velocity Measured - Average Velocity of Group
7-2	29.3	0.4
	28.7	0.7
	29.1	0.2
	28.8	-2.9
	29.1	-1.2
	29.3	-0.9
	29.2	-3.4
	29.3	-1.6
	29.6	1.2
	28.5	0.7
		-0.1
		0.3
		2.6
		3.1
		0.3



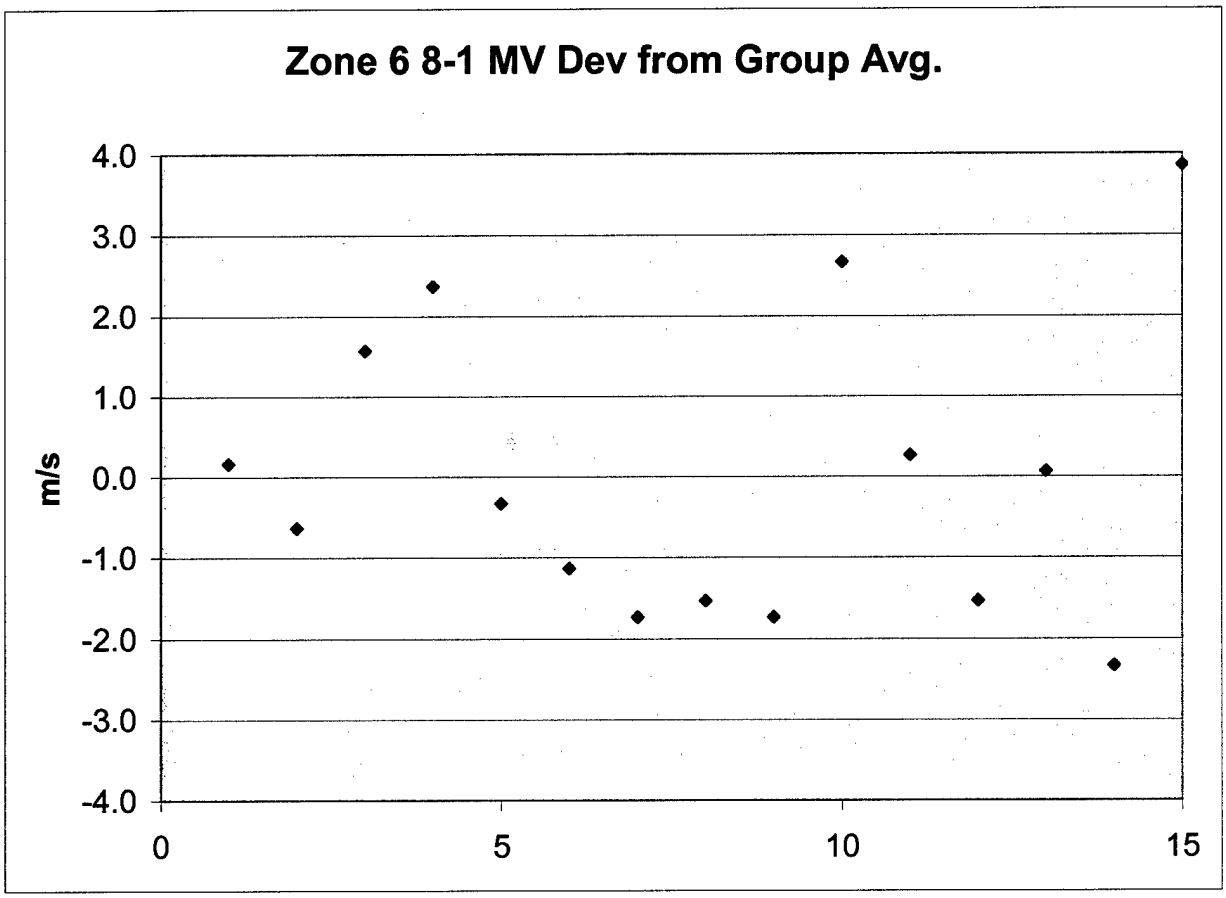
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
7-3	30.6	0.6
	30.9	0.4
	31.6	-1.7
	29.9	-0.9
	29.8	2.1
	30.2	1.1
	29.6	-0.2
	29.9	0.0
	32.6	0.6
	29.9	-1.4
		0.2
		-1.0
		0.2
		-1.6
		1.3



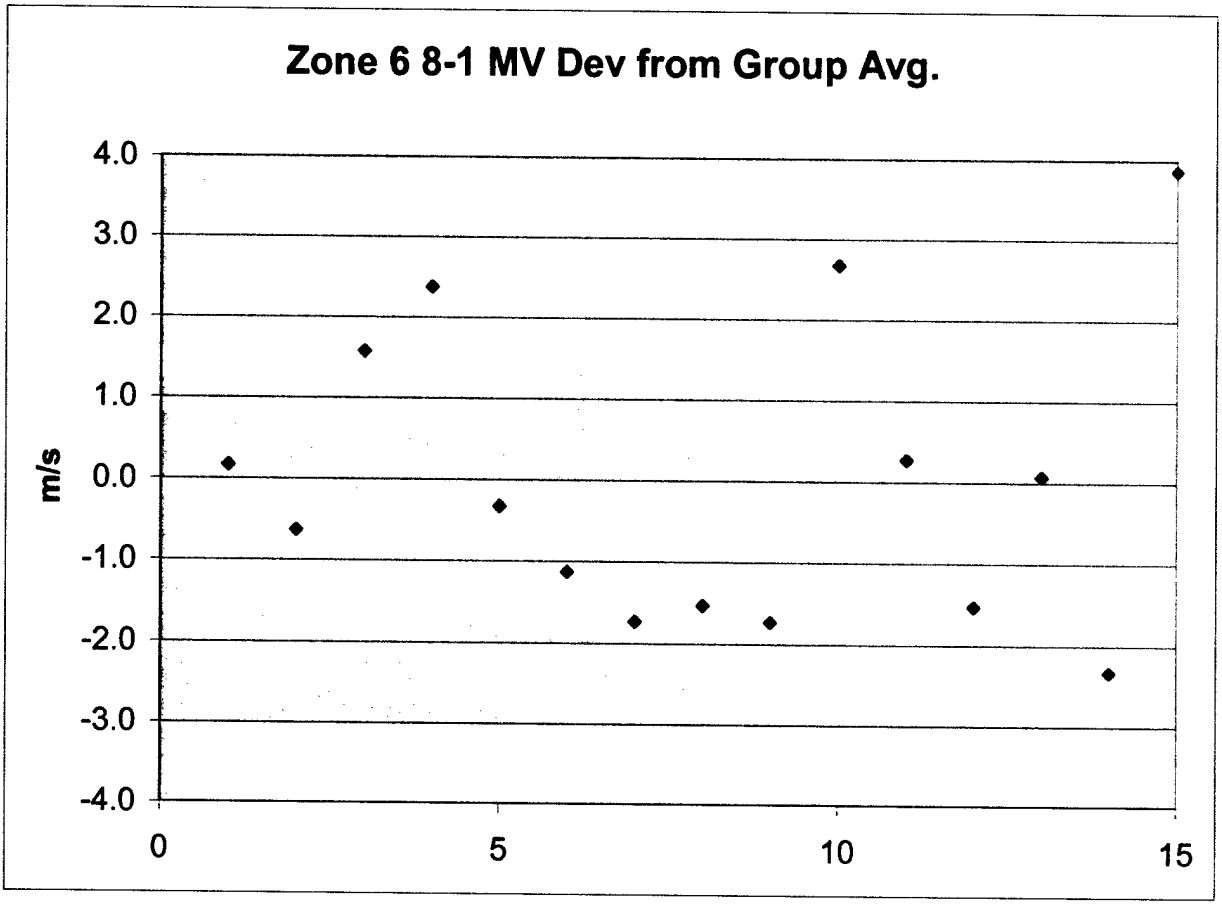
Zone 6 Mission ID	Sampled Increments Temp Θ	Velocity Measured - Average Velocity of Group
7-4	33.9	0.3
	32.5	1.1
	33.4	2.3
	34.2	-2.6
	30.6	-0.2
	30.6	-0.5
	30.4	-0.5
	31.5	0.8
	33.7	0.7
	32.0	2.0
		-1.4
		-1.4
		-1.2
		0.4
		-0.2



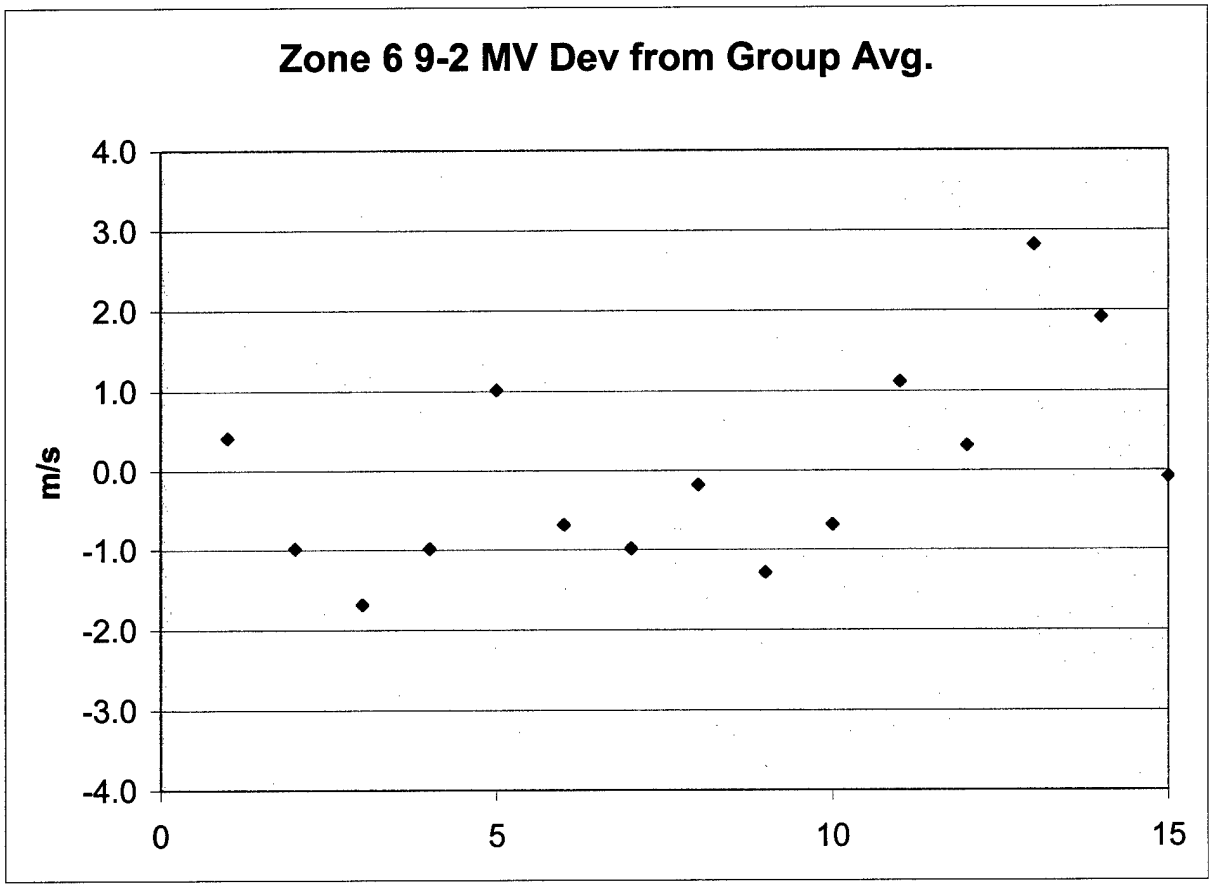
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
8-1	41.4	0.2
	40.3	-0.6
	38.7	1.6
	37.4	2.4
	35.1	-0.3
	36.2	-1.1
	35.3	-1.7
	36.1	-1.5
	37.4	-1.7
	36.1	2.7
		0.3
		-1.5
		0.1
		-2.3
		3.9



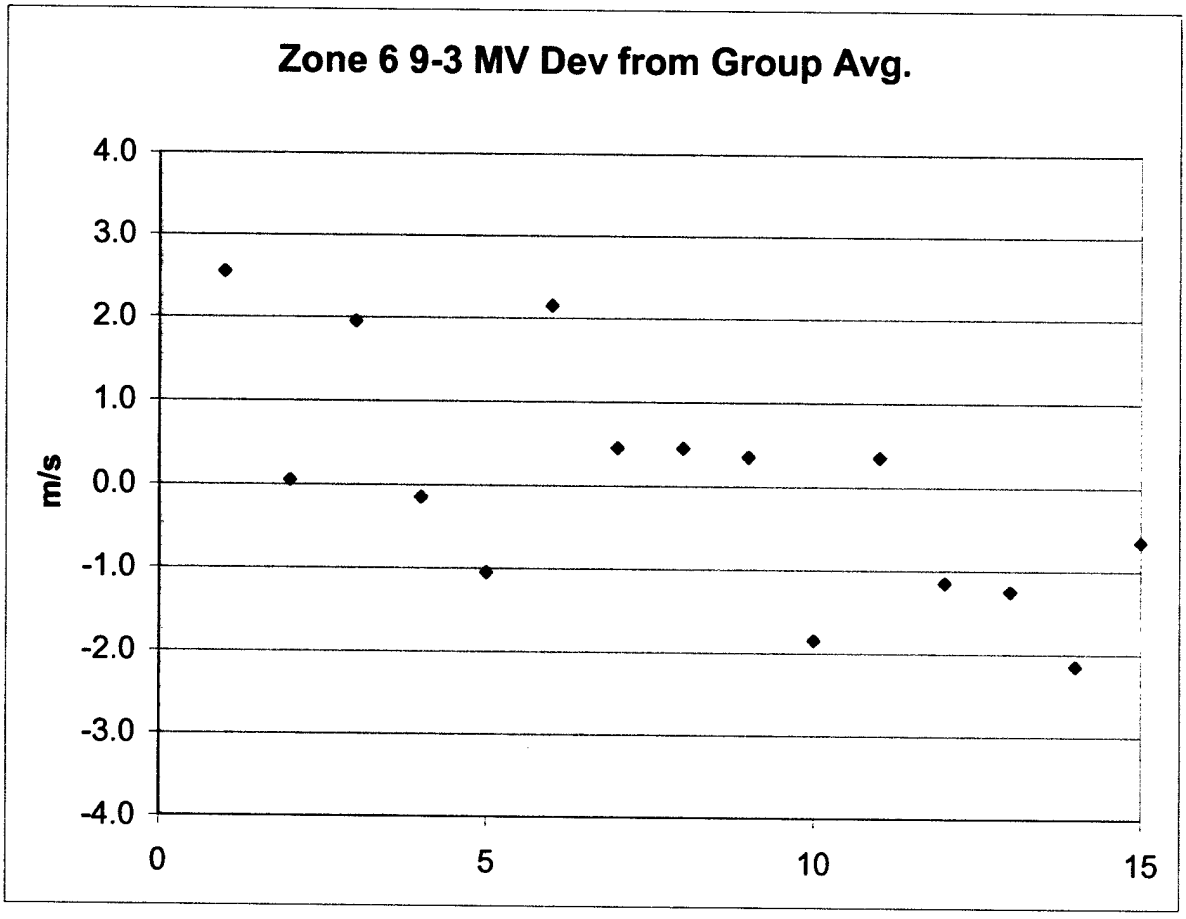
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
8-1	41.4	0.2
	40.3	-0.6
	38.7	1.6
	37.4	2.4
	35.1	-0.3
	36.2	-1.1
	35.3	-1.7
	36.1	-1.5
	37.4	-1.7
	36.1	2.7
		0.3
		-1.5
		0.1
		-2.3
		3.9



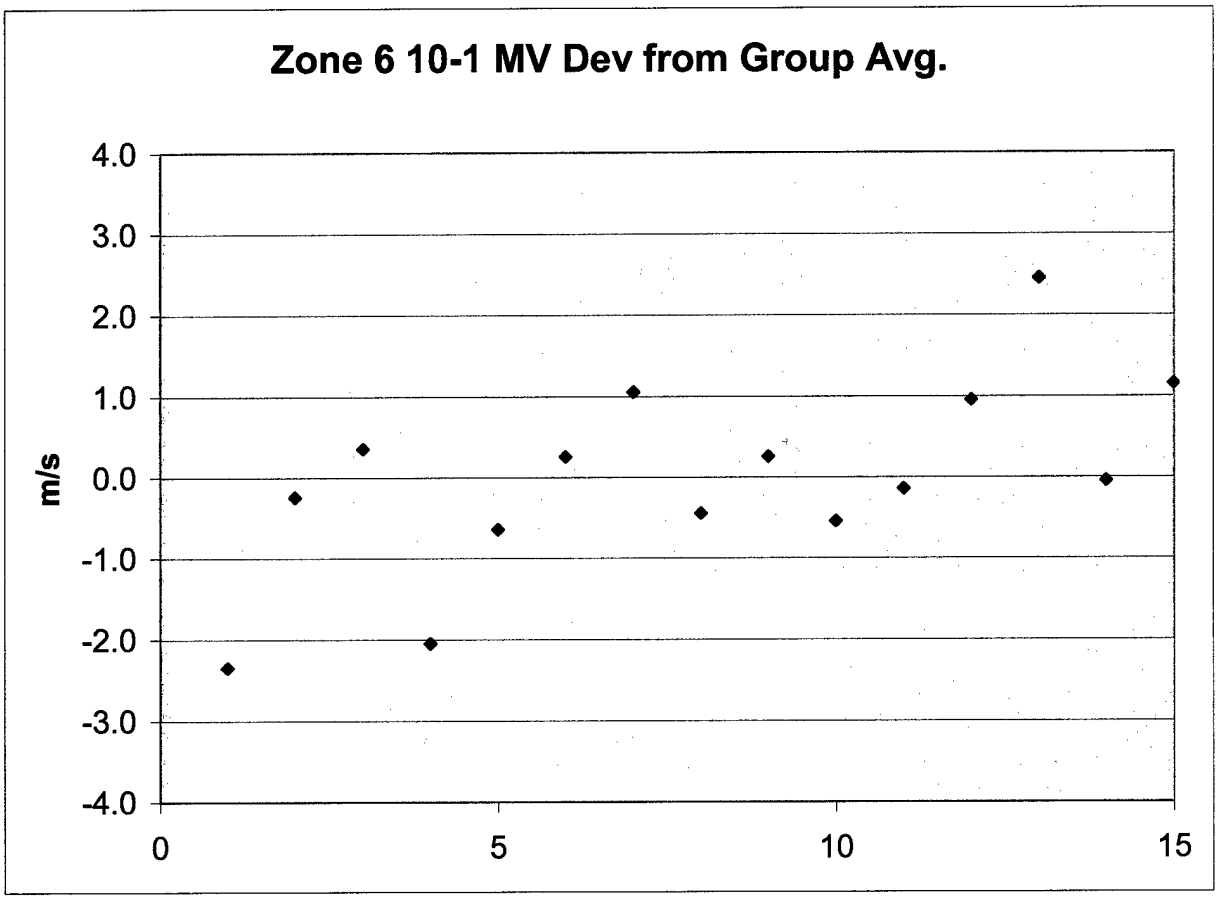
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
9-2	28.8	0.4
	29.2	-1.0
	28.7	-1.7
	29.7	-1.0
	29.3	1.0
	29.7	-0.7
	29.2	-1.0
	29.4	-0.2
	29.1	-1.3
	28.8	-0.7
		1.1
		0.3
		2.8
		1.9
		-0.1



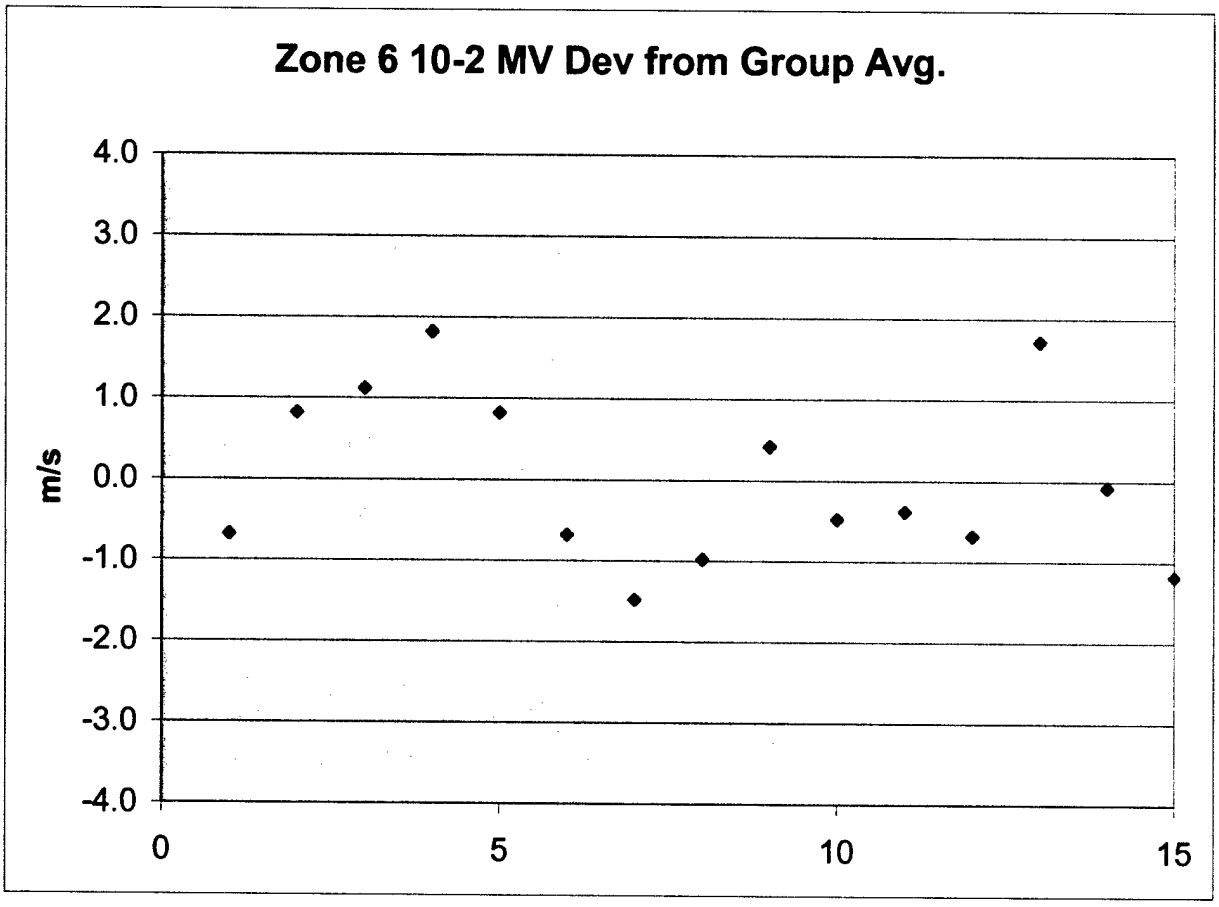
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
9-3	33.1	2.5
	32.3	0.0
	31.6	1.9
	31.4	-0.2
	31.4	-1.1
	31.7	2.1
	31.2	0.4
	31.2	0.4
	32.8	0.3
	31.8	-1.9
		0.3
		-1.2
		-1.3
		-2.2
		-0.7



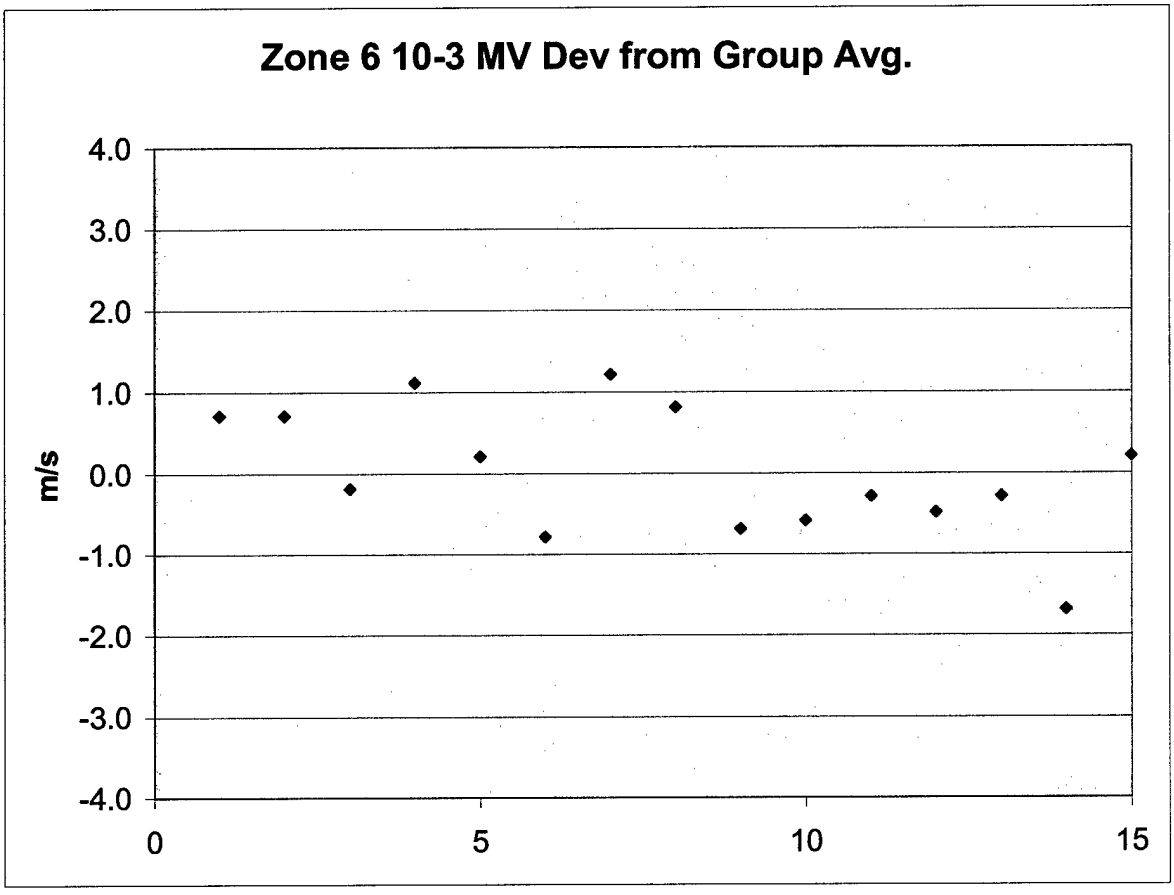
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
10-1	26.8	-2.3
	26.3	-0.2
	27.4	0.4
	26.9	-2.0
	27.7	-0.6
	27.7	0.3
	26.8	1.1
	27.2	-0.4
	28.6	0.3
	27.3	-0.5
		-0.1
		1.0
		2.5
		0.0
		1.2



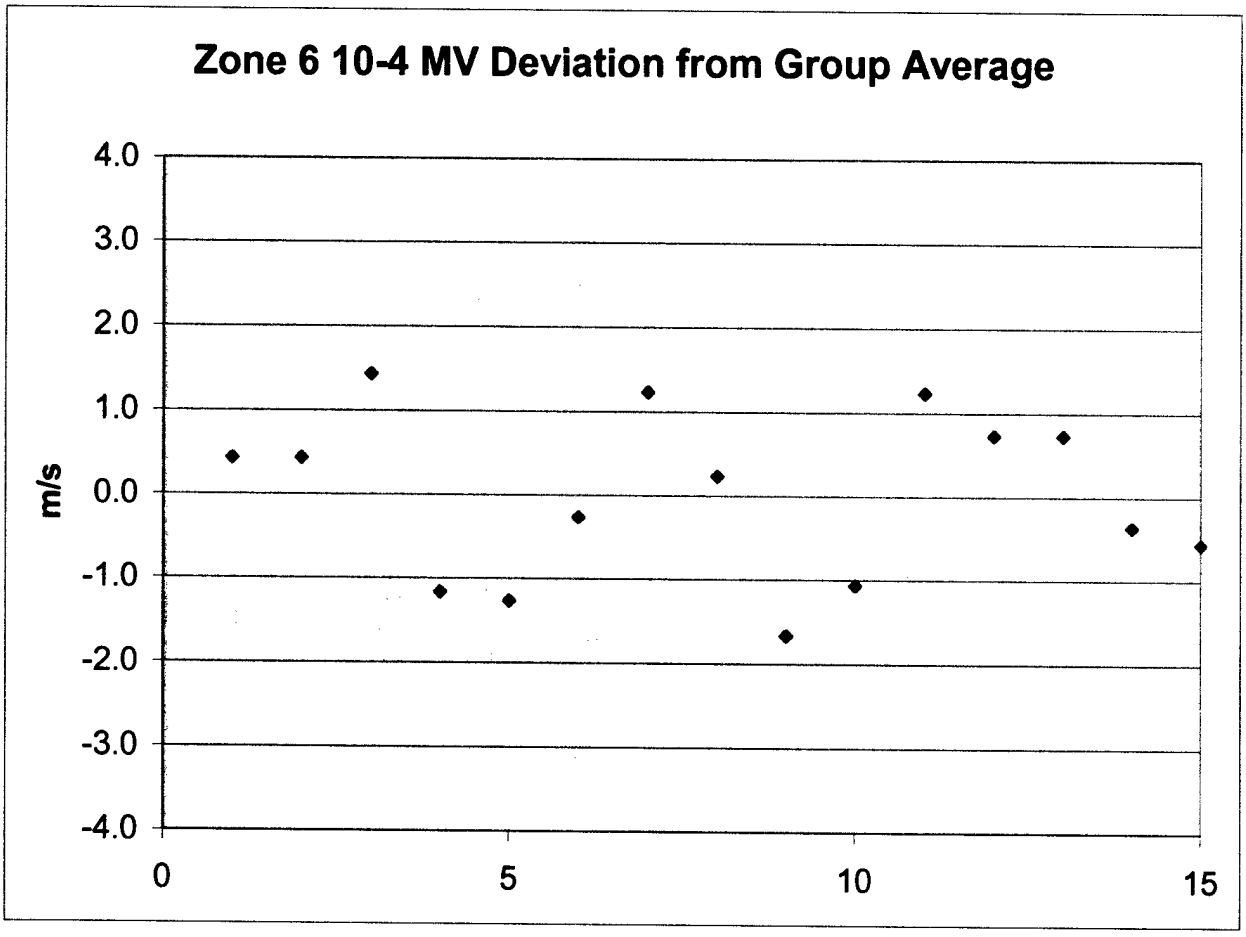
Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
10-2	29.4	-0.7
	28.4	0.8
	29.3	1.1
	28.6	1.8
	28.6	0.8
	29.3	-0.7
	28.6	-1.5
	28.8	-1.0
	29.8	0.4
	28.2	-0.5
		-0.4
		-0.7
		1.7
		-0.1
		-1.2



Zone 6 Mission ID	Sampled Increments Temp ©	Velocity Measured - Average Velocity of Group
10-3	33.9	0.7
	31.6	0.7
	32.9	-0.2
	30.6	1.1
	30.3	0.2
	30.1	-0.8
	29.7	1.2
	28.8	0.8
	31.1	-0.7
	28.8	-0.6
		-0.3
		-0.5
		-0.3
		-1.7
		0.2



Zone 6 Mission ID	Sampled Increments Temp C	Velocity Measured - Average Velocity of Group
10-4	37.3	0.4
	35.4	0.4
	37.9	1.4
	35.5	-1.2
	31.7	-1.3
	30.9	-0.3
	32.3	1.2
	36.3	0.2
	34.9	-1.7
	32.8	-1.1
		1.2
		0.7
		0.7
		-0.4
		-0.6



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